September 1983

THE NATIONAL SHIP BUILDING RESEARCH PROGRAM

Design for Zone Outfitting

U.S. DEPARTMENT OF TRANSPORTATION
Maritime Administration
in cooperation with
Todd Pacific Shipyards Corporation

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 1983	**N/A**	**-**

4. TITLE AND SUBTITLE **The National Ship Building Research Program: Design for Zone Outfitting**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Bldg Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**68**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

FOREWORD

Certainly professionalism is powerful motivation for most people engaged in ship design. The word suggests high standards and the possession of great skill or knowledge. In the context of the transition from system to zone logic now being developed by some U.S. shipbuilders, professionalism also suggests inertia, the tendency to continue in the same manner. Transition experiences are disclosing that highly professional managers of shipdesign organizations are among those most wary of change. Perhaps because each one has status in both a profession and a company, it is doubly traumatic for them to have to learn a different approach to design.

Beyond concerns for such status, there are other problems that shipyard managers have to address. The transition from system to zone orientation must address everyone in shipbuilding, not just designers. The reorganization of design information and people, based on the very effective methods developed by Ishikawajirna-Harirna Heavy Industries Co., Ltd. (IHI) as described herein, accomplishes little if not accompanied by commensurate reorganization of production people and work. Most significantly, each production department and shop must have a production engineering capabfity that can organize work in accordance with modem principles and that can ***describe the*** work so organized. Educated production engineers pervading shops are essential for devising and conveying a building strategy that must be incorporated in design documents including those produced during contract design.

Also, traditional design managers are constantly reacting to emergencies and many are charged with developing computer applied methods. To say that they are generally harassed could bean understatement. In addition to their now having to learn a new approach they are burdened with teaching their people different methods. Until zone logic is assimilated, their's are hellish workloads. Thus, special assistance in the form of transition staffs and/or consultants is generally necessary.

The methods described herein and in a companion publication, Integrated Hull Construction, Outfitting and Painting - May 1983, require ship designers to perform more work. However, the payoff in increased productivity by the entire shipbuilding system makes it very worthwhile.

ACKNOWLEDGEMEN7S

This publication was produced for the Los Angeles Division of Todd Pacific Shipyards Corporation by L.D. Chirillo Associates of Bellevue, Washington.

The material on which the contents are based was compiled by a project team led by Y. Okayama, International Division, Ishikawajirna-Harirna Heavy Industries Co., Ltd. (IHI) of Japan. Team members included T. Yamarnoto, H. Sasaki and N. Teramoto. Their work was significantly rewritten, supplemented and reorganized by L.D. Chirillo assisted by R.D. Chirillo.

Appreciation is expressed for comments received from Newport News Shipbuilding and from Nickum & Spaukling Associates of Seattle, the first U.S. design firm to initiate development of a zone-oriented ship design capability. Appreciation is also expressed to Y. Ichinose of IHI Marine Technology, Inc. and to T. Lamoureux, L. Willets, D. Arnold and B. Coralles of Todd's Los Angeles Division, who furnished essential support.

This publication is an end product of one of the many projects managed and cost shared by Todd for the National Shipbuilding Research Program. The Program is a cooperative effort by the Maritime Administration's Office of Advanced Ship Development and the U.S. shipbuilding industry. The objective, described by the Ship Production Committee of the Society of Naval Architects and Marine Engineers, is to improve productivity.

This book is dedicated to the memory of
a shipbuilder
from Newport News, Virginia

Lloyd C. Clevinger
April 18, 1935— July 24, 1983

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1.0 INTRODUCTION

For ship design, organizing information system by system is effective for creative purposes and for soliciting owner and regulatory approvals. There was a time when the same organization of information was effective for specifying outfit work to be accomplished by referencing system arrangement drawings. However, the advent of welding revolutionized shipbuilding. Steel is now processed everywhere in accordance with variations of the Hull Block Construction Method (HBCM). Literally, hulls are constructed block by block just as the Egyptians built the pyramids.

Because of the availability of blocks, production people shifted to *preoutfitting* by extracting bits of information from a number of system drawings in order to collect the information needed to install portions of various systems in a single block. Productivity is inherently limited because outfit design, material definition and material procurement are in accordance with a system-by-system strategy whereas outfitting work is in accordance with a conflicting zone-by-zone strategy, Thus, some shipbuilders extended the logic of HBCM to create the Zone Outfitting Method (ZOFM) and the Zone Painting Method (ZPTM).' This forced their outfit designers to become product oriented, i.e., to produce drawings that define work packages by zones and that do not require further processing by production people. Significant differences from conventional design are:

- elimination of many expensive and time consuming system arrangement drawings,
- identification of outfit work packages by *product asoects* on composite drawings,
- material lists structured to match the outfit work packages, and
- in usage of terminology and organization of design phases.

1.1 Product Aspects

The word *zone is* used to define an *interim product* (interim goal) which is a somewhat cubic subdivision of a contemplated ship. As employed for outfitting, a zone encompasses a group of fittings, regardless of system, which are to be assembled:

- without the presence of any hull structure, i.e., *oufitting on-unit,*
- on ceilings when blocks are upside down and separately on decks when blocks are turned over, i.e., *on-block outfitting,* and
- during and after hull erection, in a compartment, part of a compartment or any combination of compartments, i.e., *on-board outfitting.*

When a *stage* is specified, i.e., a step in progress, a *zone/stage* designates specific work and reserves a specific space for a worker or work team regardless of the systems represented. Thus, different work teams are coordinated by zone/stage classifications. Work teams no longer have to compete with each other for access to work.

When such work packages are sorted by implementation considerations, they are said to be classified by problem *area.* Regardless of design differences, work packages of the same problem area, each contrived to have about the same work content, are executed in real or virtual work flows. in accordance with the principles of group technology, many different outfit jobs required in varying quantities are homogenized.

In the most effective shipyards, the triad *zone/area/stage* has almost completely replaced system for organizing outfit work. Work packages so classified:

- facilitate resource allocations, schedulingand assessments of progress and productivity, and
- impose certain disciplines on designers including those who prepare contract plans.

The interaction of the Hull Block Construction Method (HBCM). zone Outfitting Method (ZOFM) and the Zone Painting Method (ZPTM) is described in "Product Work Breakdown Structure (PWBS) - Revised December 1982". Outfit Planning - December 1979" is also pertinent. Both, as well as other National Shipbuilding Research Program publications referenced herein, are available to U.S. shipbuilders in limited quantities from: L.D. Chirillo Associates, P.O. Box 953, Bellevue, WA 9S009.

1.2 Pallet

The word *pallet* has been adopted as a convenient means to associate *all information and resources* needed for executing a unit of work classified by zone/area/stage. As it applies to more than the collection of materkd, *pal/et is* employed as a concept.

In terms of information and resources *pallet* means for:

- *design* - a drawing and its material list,
- material procurement - a complete kit of materials, and for
- production - work volume, manpower and facilities.

Specifically in scheduling matters *pallet* means for:

- *design* - completion and issue dates for a drawing and its material list,
- material procurement - a date for issue of a material kit, and for
- production- allocation of man-hours and facilities dur. ing a specific time period.

1.3 Design Phases

The design effort controlled by the shipbuilding firm is implemented in four phases as shown in Figure 1-1 and as described in the following

- *Basic Design describes* a ship as a total system. It is sometimes based on an owner-sponsored preliminary design which *generally* fixes what the ship is to be and how it is to perform. Depending on complexity and the shipyard's experience with the owner, the end-products are specifications and *contract plans* which may be limited to only a general arrangement and midship section or may be relatively extensive and detailed.
- *Functional Design* addresses each system in quasi-arranged diagrammatics for piping and wiring and in system plans such as for a mooring system. Such documents are sufficient for owner and regulatory approvals and are called *key plans.* A *material list by system (MLS) is* prepared for each diagrammatic and system drawing.
- *Transition Design* regroups information organized by systems so as to organize the same information by zones. This first interrelationship of systems and zones, expressed on *yardplans, is* needed to guide the development of specific work instructions.
- *Work Instruction Design* groups design information by the additional product aspects, area and stage, which are classifications of the manufacturing processes. This applies to both *fitting work instructions* for assembly work and *manufacturing work instructions* for pipe pieces and other components. In sophisticated organizations, work instruction design is regarded as an extension of transition design and end products are regarded as yard plans. Elsewhere, as in this publication, it is helpful to maintain separate identity of work instruction design and to call the end products *stage pians.* A material list for fitting (MLF) is prepared for *each fitting* work instruction. A material list for manufacturing a pipe piece (MLP) or a material list for manufacturing a component other than pipe (MJX), accompanies each *manufactturing* work instruction.

1.4 Information Routes

Starting during basic design and throughout the remaining design phases, production engineers from the hull construction department exchange information with the hull structural design group about matters such as block definition, the hull construction production plan and yard plan need dates. While this is going on, outfitting field engineers collaborate with outfit designers principally concerning pallet deftition, the outfitting production plan and pallet need dates.

Simultaneously, outfit designers are advising the hull structural group of outfit requirements for holes and reinforcements in structure. Sirnilariy, outfit field engineers are communicating with hull construction field engineers concerning requirements for outfitting on-block and on-board. Meanwhile, outfit designers are defining outfit components and raw material requirements as field engineers determine need dates per pallet. These are conveyed to procurement people by requisitions in advance of the lead times provided by the procurement people. Typical information paths for this" great interchange of information necessary for integrated hull construction, outfitting and painting (IHOP), are illustrated in Figure 1-2. *Throughtout, pallets serve as essential communication links.*

' More knowledge of the information interchange is contained in the National Shipbuilding Research Program publication "Integrated Hull Construction, Outfitting and Painting (IHOP) - May 1983"'.

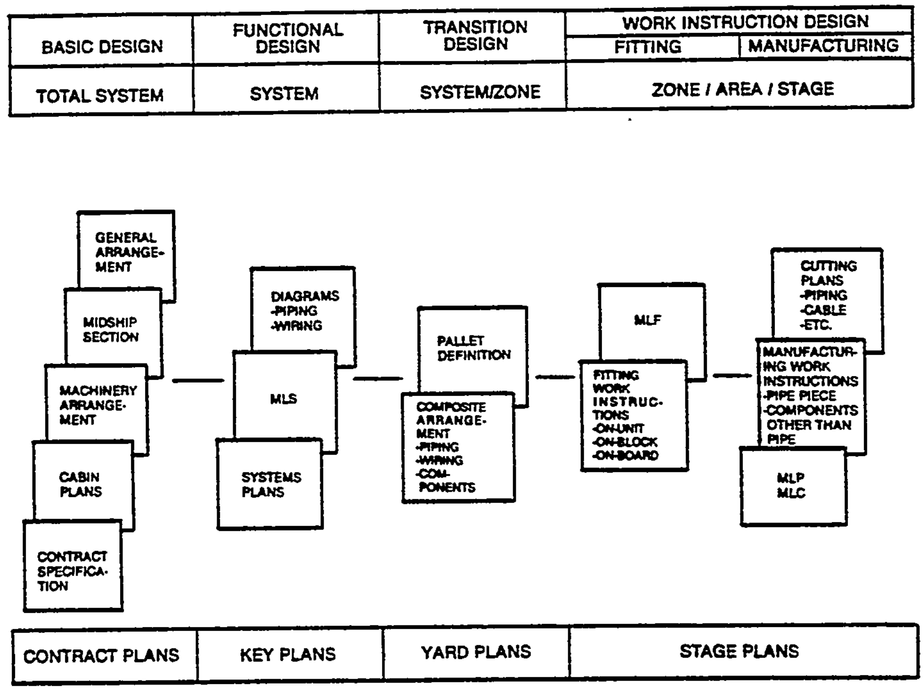

FIGURE 1-1: Product-oriented design process. As design progresses, a transition is made from system to zone.

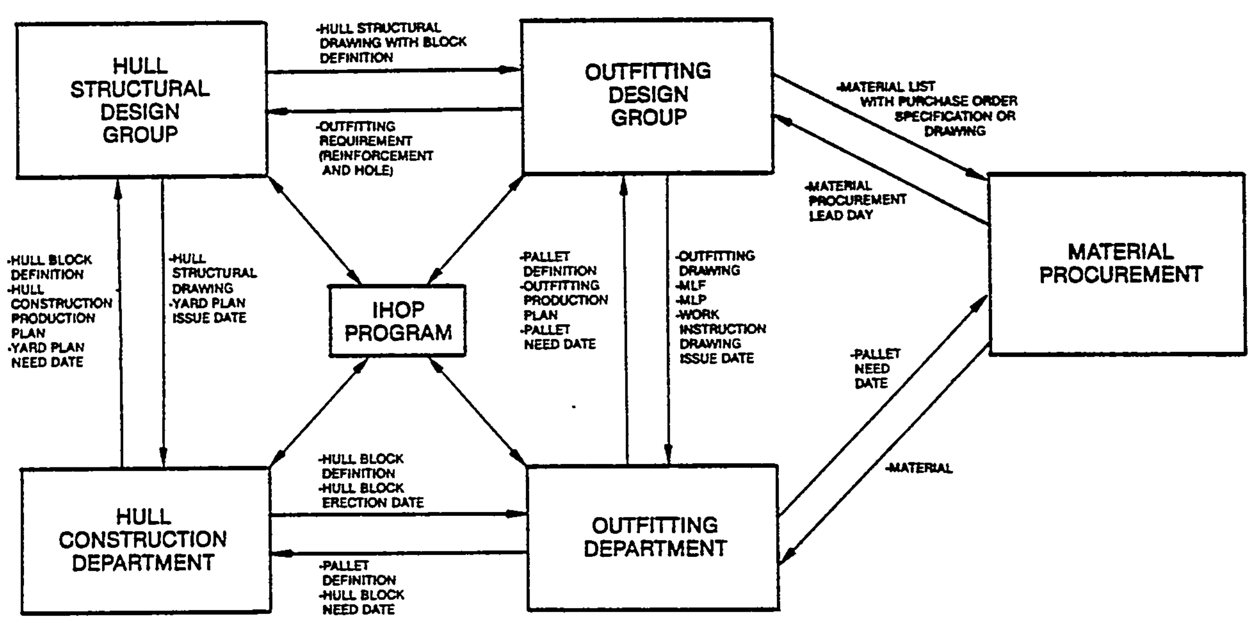

FIGURE 1-2: Information interchange for Integrated Hull Construction, Outfitting and Painting (IHOP).

2.0 DESIGN ORGANIZATION

The design effort may be regarded as an information service preceding but not ruling the production process. How well designers group information to anticipate the way a ship is to built is very dependent upon abilities of production engineers to organize and describe their building strategy and work processes. Such descriptions are required to an appreciable extent even by people who perform basic design.

2.1 Basic Design

Basic design, i.e., describing a ship as a total system, justifies a system-oriented organization which can be:

- a separate department located in the head office of a firm having more than one shipyard,
- a separate department in a shipyard or even a separate group within a yard's ship design department, or
- an independent design firm.

Regardless of where basic design is performed the same communication problems exist. Contract plans such as a midship section and machinery arrangement must reflect block pre-definition based on a particular pre-strategy for outfitting. Timely and formal documentation of both by production engineers from hull construction, outfitting and painting shops are *viral* for productive shipbuilding.

Phasing the remaining production planning effort to match the remaining design phases is also essential. The necessary exchange of much information between production and design engineers for outfitting is greatly enhanced when both are organized to address the same problem areas in commensurate degrees of detail.

2.2 System vs. Zone Organization

For the phases following basic design, outfit design organizations are broadly classified into two types both of which are in the context of product aspects, i.e., they are either system or zone oriented.

Traditional system-oriented design organizations typically address few interim products, are divided only into *hull, mechanical* and *electrical* groups and are further segmented to address outfitting:

- on deck and in cargo compartments *except* machinery, piping, ducting and electrical systems,
- in living quarters *except* piping, ducting and electrical systems,
- for arrangement and definition of machinery, such as a main engine, boiler, pump, windlass, steering gear, etc., *except* for associated piping, ducting and electrical systems,
- piping systems throughout,
- ducting systems throughout, and
- electrical systems throughout.

Different ships impose questions such as who is responsible for ramp operating machinery in roll-on roll-off ships, who has cognizance of deep-sea winches in oceanographic ships, who is responsible for laundry equipment, etc.

Even for the same system, the problems encountered in fitting components in a machinery space are generally different from those in an accommodation space or elsewhere. Thus, in further accordance with group technology logic and because of the use of composites vice system arrangements, organization of people by specialties other than systems makes sense.

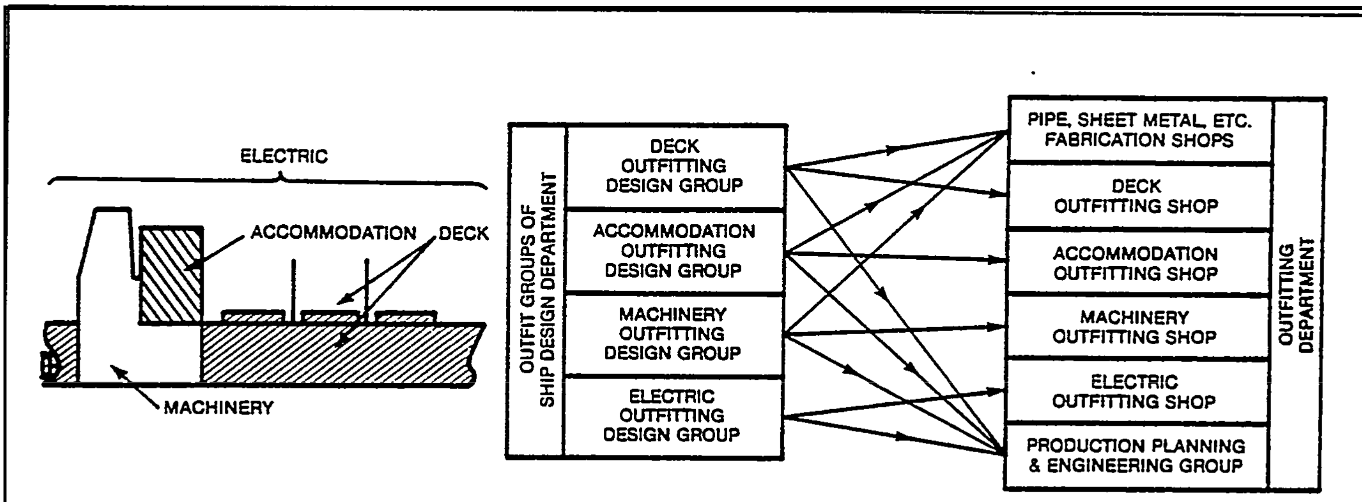

FIGURE 2-1: **Design and production people are organized to specialize by the fabrication and assembly problems associated with *deck, accomodation, machinery and electrical* (DAME). For warships, a *weapons* specialty is added. Although fabrication shops are shown, all or part of such work can be assigned to subcontractors.**

Where effectively applied, the specialties are *deck, accommodation, machinery and electrical (DAME)* for both a shipyard's design and production efforts as shown in Figure 2-1. In the machinery outfitting design group, for exampIe, pipe- and ventilation-system designers work for the same supervisor and are commonly responsible for developing interference-free composites which reflect ideal interim products classified by zone/area/stage. They have production engineer counterparts in the machinery outfitting shop and the *pallet* concept as a basis for communicating. Such designers are led away from unjustified, time consuming fine tuning of systems and are instead. focused on parts-fabrication and assembly productivity. Because of specialization in the DAME or zone organization, detail designers develop concentrated expertise per zone as do their shop counterparts.

In a system organization, for example, a detail designer develops a piping-system arrangement from a previously developed diagrammatic and usually specifies supports independent from those required for other systems. After the most difficult systems are arranged, other system routes are defined on a space available basis and are characterized by relatively numerous unique-angle bends, varying pipe-piece lengths and additional independent supports. Material lists are prepared by system regardless of outfit-shop needs to organize materiaI per work package. Where preoutfitting is practiced, regrouping of material is left for production organizations to perform.

2.3 *Organization by Deck, Accommodation, Machinery and Electrical*

In a DAME organization, work instruction designers are provided with zone/area/stage definition beforehand and are further guided by unique composites prepared during transition design. For each zone, as much as possible, distributive systems are regimented in parallel, feature limited bends mostly of 90 degrees and share common supports including those needed for walkways. Significantly, detail designers list material per zone/area/stage.

A DAME organization facilitates product-orientation, i.e., conception of intermediate subassemblies needed to make larger assemblies, because:

- **designers are provided with interface guidance, and**
- **definition by zone/area/stage permits integrated sche-**duling for design, material procurement and production as well as for coordination of the various outfit groups in a ship design department.

Modern zone-oriented design *organizations* specifically address interim products and have now progressed to the extent that virtually all outfit responsibilities are organized in accordance with DAME specialties. Effective product-oriented designers are organized to separately address:

- **deck - everything on and in the hull *except* machinery spaces (usually only engine and pump rooms) and electrical systems,**
- **accommodation - everything on and in the deckhouse *except only* electrical systems,**
- **machinery - everything in machinery spaces including the uptakes and funnel *except only* the electrical systems, and**
- **electrical - which includes all electrical and electronic** systems regardless of their locations.

Such DAME organizations are charged with preparation of key plans as well as yard plans. Incorporation of system-onented key plans seems to be a paradox. However, as diagrammatics are quasi-arrangements, each DAME group is responsible for producing only the portions which pass through its specialty region. Obviously, good communications between the groups are necessary.

Some advantages of the DAME organization as compared to traditional separation of outfit design only by *mechanical* and *electrical are:*

- clear definition of outfitting responsibilities by geographical regions common to most ships, i.e., each new design imposes few questions about who is responsible for what,
- development of zone expertise to supplement command of traditional design disciplines,
- enhanced ability to exploit standardized and modularized pallets, and
- greater flexibility for shifting designers commensurate with changing workloads.

2.4 Responsibilities

The totality of the responsibilities assigned for zone-oriented design in some extremely productive shipyards is exemplified by their accommodation outfitting design groups which prepare plans for:

- *superstructure and deckhouse structure,*
- life boats, and
- all other *accommodation* fittings except for electrical systems.

Thus, association of a design group's responsibilities with a unique zone clarifies almost all fitting responsibilities.

The responsibilities for other requirements, such as, *trim* and stabtity calculations, sounding tables, painting and testing specifications, etc., require equivalent clarification. Whether these responsibilities are assigned to an especially created group or apportioned among the hull structural and DAME groups is determined on a case-by-case basis in consideration of organization size, qualifications designers, design workload, etc.

Responsibilities for standardization and modularization of pallets and research and development, including that for design methods, are more effectively implemented when apportioned among the DAME groups. This sharing is very important because during routine design work, consideration should be constantly given to how to improve both the design and the design system. The *obligation to improve the system never ceases. Centralizing* such responsibilities in an independent group causes objectives to deviate from real needs. When, for example, there is to be a large standardization project, an ad hoc committee made up of representatives from concerned groups and chaired by a specialist or senior manager, is preferred.

Experience in some of the most effective shipyards indicates that 20 to 30 people are usually within a group manager's abtity to control. If the workload is such that more than thirty people are required for a group, further division of the ship design department into separate key and yard plan sections, as shown in Figure 2-2, is prudent.

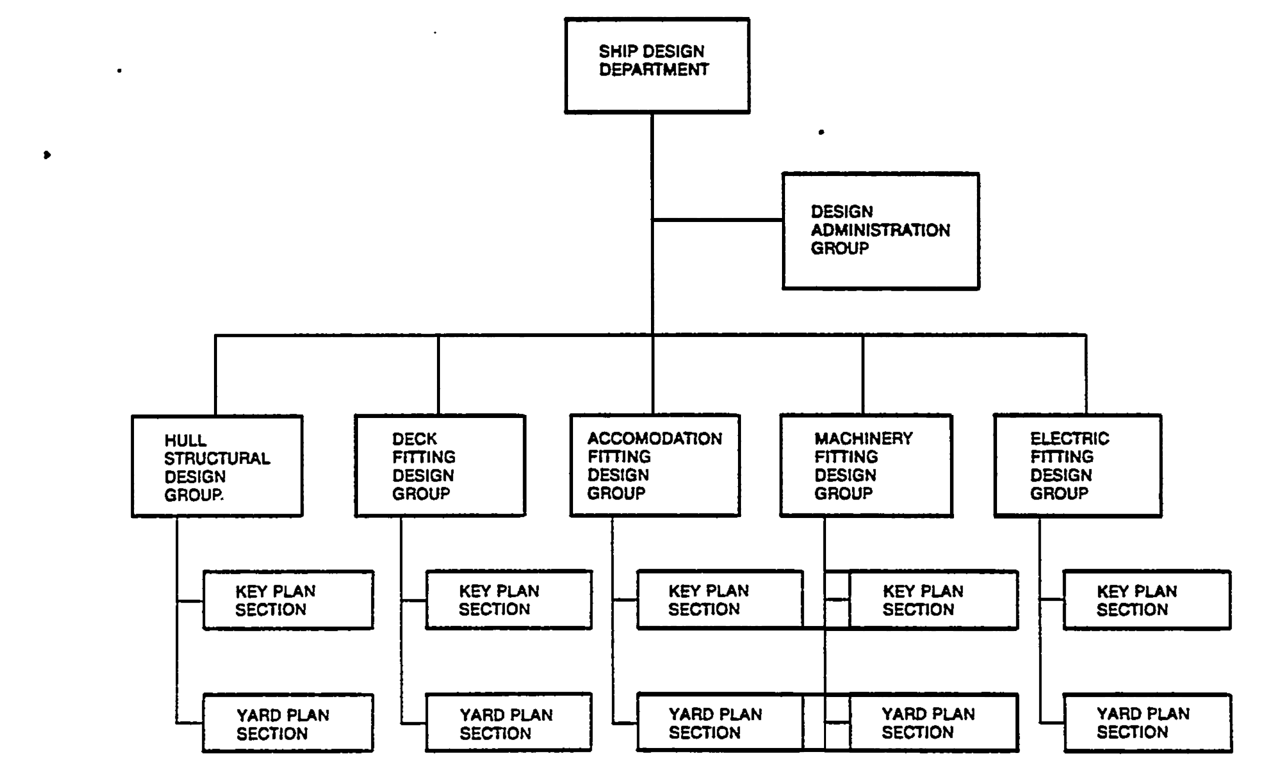

FIGURE 2-2: Typical organization for a zone-oriented ship design department. Basic design, not shown, is usually performed elsewhere.

Where zone orientation is most advanced, ***hull structural*** stage plans, i.e., work instructions, are assigned to production people. Stage plans for parts fabrication are prepared in the mold loft. Those for sub-block assembly, block assembly and hull erection are assigned to a ***stage plan section*** which is a companion organization to the mold loft. similarly, preparation of ***outfitting stage plans is*** assigned to stage plan sections managed by experienced production engineers of the DAME shops because they have the best knowledge of production processes.

However, designers also qualify by having immediate expert knowledge of the .developing design and material requirements. Thus, where outfitting stage plans are best prepared is dependent on the particular circumstances during a given time in each shipyard. Because their preparation must be faithfully in accordance with guidance prepared during transition design and because of the DAME separations, splitting the responsibility can be practical. For example, the preparation of stage plans for ***machinery and electrical*** could be managed by design engineers while the preparation of ***deck and accommodation*** stage plans is being managed by production engineers.

To the extent assigned as a design responsibility, stage plans are prepared by the same people who prepare yard plans during transition design. Thus, in a modest size design organization each DAME group prepares key, yard and stage plans. For the same reasons, assigning all or part of the stage plan effort to design subcontractors is very practical. The yard plans prepared in house serve to convey the shipbuilding strategy with more than sufficient detail for specifying and controlling the subcontracted work.

Specific responsibilities assigned in such ship design departments, a few are noted in Figure 2-3, are:

2.4.1 ***Design Administration Group***

- integration and control of the master design schedule,
- tracking and control of drawing issues,
- administration of submittals for approval by owners and regulators,
- control of the ship design department budget, and
- general affairs of the ship design department.

2.4.2 ***Hull Structural Design Group, Key Plan Section***

- **strength and vibration calculations for hull structure,**
- **key plans for:**
  - refined midship section and typical transverse bulkhead,
  - structural lines (frame offsets),
  - Scantling,
  - stem frame,
  - rudder, rudder stock and carrier,
  - main engine, foundation and major auxiliary machinery foundations,
  - welding scheme, etc.
- plans to be delivered to the owner (record plans, etc.), and

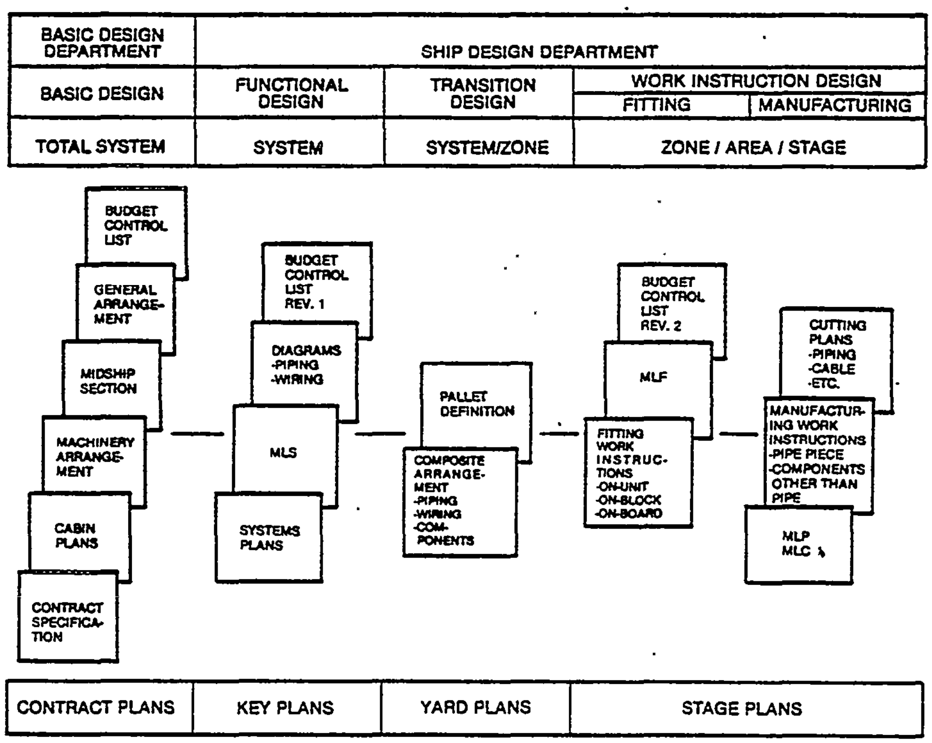

FIGURE 2-3: Product-oriented design process showing the budget control ***LIST*** and its revisions.

- material lists by hull structural systems and the first revision to the ***hull*** material quantities contained in the budget control list originally prepared during basic design.

2.4.3 ***Hull Structural Design Group, Yard Plan Section***

- block plans (yard plans) including some further development of structural design,
- block parts lists,
- hull parts and sub-block drawings,
- fabrication plans for main engine and major auxiliary machinery foundations, and
- material lists per block and the second revision to the ***hull*** material quantities contained in the budget control list.

2.4.4 Deck Outfitting Design Group, Key Plan Section

- ***deck*** purchase specifications and approvals of vendors' drawings,
- refined general arrangement,
- ***deck*** piping diagrammatic and guidance,
- fire-fighting plan,
- mooring plan,
- Argo gear plan,
- access plan, etc.
- manufacturing drawings for ***deck*** long-lead time materials,
- test guidance and record forms,
- plans to be delivered to the owner, and
- material lists by system (NILS) and ***the first*** revision to ***the deck*** material quantities contained in the budget control list originally prepared during basic design.

2.4.5 ***Deck Outfitting Design Group, Yard Plan Section***

- the first interrelationships between ***deck systems*** and zones to be used as guidance for preparation of composite arrangements,
- final pallet definition,
- composite arrangements and separate outfitting arrangement drawings to provide sufficient assembly work instructions for ***deck*** outfitting on-unit, on-block and on-board,
- material lists for fitting per pallet (MLF) and the ***second*** revision to the ***deck*** material quantities contained in the budget control list,
- manufacturing drawings for ***deck*** oufit components and their separate material lists, i.e., material list for manufacturing a pipe piece (MLP) and material list for manufacturing a component other than pipe (MIX),
- ***deck*** outfitting weights and centers of gravity.

2.4.6 Accommodation Outfitting Design Group, Key Plan Section

- ***accommodation*** purchase specifications and approvals of vendor's drawings,
- cabin plan including lighting and access plans,
- plans for superstructure and machinery casing structure including the funnel,
- deck covering plan,
- insulation plan,
- lining plan,
- piping and ventilation diagramrnatics and guidance,
- refrigerated provisions stores plan,
- life saving plan,
- manufacturing drawings for long-lead time outfit components identified on MLS,
- test guidance and record forms,
- plans to be delivered to the owner, and
- material lists by system (NILS) and the first revision to ***the accommodation*** material quantities contained in the budget control list originally prepared during basic design.

2.4.7 ***Accommodation Outfitting Design*** Group ***Yard Plan Section***

- fabrication and assembly yard plans and material lists for superstructure and machinery casing structure,
- the first interrelationships between systems and zones to be used as guidance for preparation of composite arrangements,
- final pallet definition,

- composite arrangements and separate outfitting arrangement drawings to provide sufficient assembly work instructions for outfitting on-unit, on-block and on-board,
- material lists for fitting per pallet (MLF) and the ***second*** revision to the ***accommodation material*** quantities contained in the budget control list,
- manufacturing drawings for ***accommodation*** outfit components and their separate material lists, i.e., material list for manufacturing a pipe piece (MLP) and material list for manufacturing a component other than pipe (MLC),
- ***accommodation*** outfitting weights and centers of gravity.

2.4.8 Machinery Outfitting Design Group, Key Plan Section

- ***machinery*** purchase specifications and approvals of vendors' drawings,
- refined machinery arrangement,
- ***machinery*** piping diagrammatic and guidance,
- shafting and propeller plans, etc.,
- manufacturing drawings for long-lead time outfit components identified on MLS,
- test guidance and record forms,
- plans to be delivered to the owner, and
- material lists by system (NILS) and the first revision to ***the machinery*** material qualities contained in the budget control list originally prepared during basic design.

2.4.9 Machinery Outfitting Design Group, Yard Plan Section

- ***the*** first interrelationships between systems and zones to be used as guidance for preparation of composite arrangements,
- final pallet definition,
- composite arrangements and seaparate outfitting arrangement drawings to provide sufficient assembly work instructions for outfitting on-unit, on-block and on-board,
- material lists for fitting per pallet (MLF) and the ***second*** revision to the ***machinery*** material quantities contained in the budget control list,
- manufacturing drawings for ***machinery*** outfit components and their separate material lists, i.e., material list for manufacturing a pipe piece (MLP) and material list for manufacturing a component other than pipe (MLC),
- ***machinery*** outfitting weights and centers of gravity,

2.4.10 ***Electric Outfitting Design Group, Key Plan Section***

electric purchase specifications and approvals of vendors' drawings,

electric **diagrammatics** and systems plans such as:
- panel arrangements for switchboards, group starter panels, the engine control console, etc.,
- schematic wiring diagrams,
- arrangement of navigation equipment, etc.

electric load analysis,

manufacturing drawings for long-lead time outfit components identified on MLS,

test guidance and record forms,

plans to be delivered to the owner, and

material lists by system (MIS and the first revision to the ***electric*** material quantities contained in the budget control list originally prepared during basic design.

2.4.11 ***Electric Outfitting Design Group, Yard Plan Section***

- the first interrelationships between ***electric*** systems and zones to be used as guidance for preparation of composite arrangements,
- final pallet definition,
- composite. arrangements and separate outfitting arrangement drawings to provide sufficient assembly work instructions for ***electric*** outfitting on-unit, on-block and on-board,
- cable cutting plan,
- material lists for fitting per pallet (MLF) and the second revision to the ***electric*** material quantities contained in the budget control list,
- manufacturing drawings for ***electric*** outfit components and their separate material lists, i.e., material list for manufacturing a ***cable-conduit*** piece (MLP) and material list for manufacturing a component other than pipe (MLC),[1]
- ***electric outfitting*** weights and centers of gravity.

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[1] Cable-conduit pieces are manufactured in the pipe fabrication shop as if they were pipe pieces. Thus, MLP are used by the electric group to list material per conduit piece.

2.5 Organizational Flexibility

Immediate design responsibtities in a product-oriented ship design department are ideally divided among groups for:

- hull structure,
- deck outfitting,
- accommodation outfitting,
- machinery outfitting, and
- *electric* outfitting.

Every group (or section in a large organization which has divided each group into key and yard plan sections) is divided into teams each of which is made up of an engineer-in-charge, assistant engineers and draftsmen. A team is assigned to produce *all* plans within its specialty for a specific *ship*. For example, in a modest size ship design department, one such team of the machinery group is assigned to produce key plans, yard plans and stage plans for a particular ship's engine-room. The engineer-in-charge of the team is responsible for coordination and for decisions regarding ship operational and maintenance functions, shipbuilding matters such as pallet definition, arrangements, material definition, etc. and cheeking design end-products. The draftsmen respond to the engineers' instructions for ordinary design work.

The different natures of modern ships and fluctuating backlogs that characterize shipbuilding are constantly changing the balance of work within a DAME group. Thus, the administrative structure of each group is flexible enough to permit constant workload leveling and balancing.

As the design workload for a particular team diminishes, team members can be *rotated* to assist other teams in accordance with changing workloads. When there is no ship-design assignment, the surplus team is assigned as an entity to assist the team having the greatest workload. Figure 24 illustrates how individuals and even a whole team ean be rotated as means for workload leveling and balancing within a group. Figure 2-5 illustrates a leveled and balanced workload.

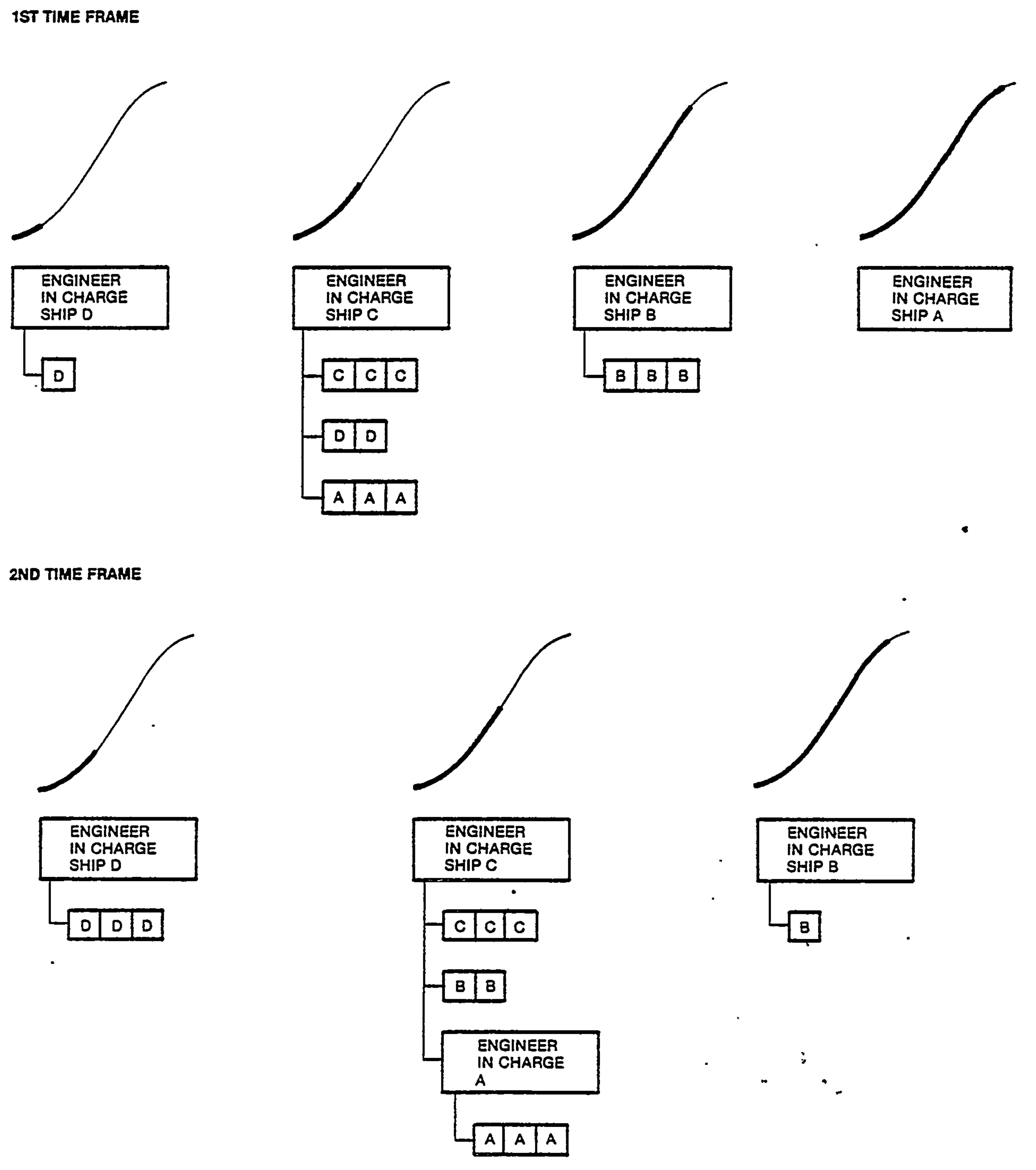

FIGURE 2-4: Only within a specialty, machinery for example, assistant engineers and drafters are assigned to a team having functional, transition and work instruction design responsibilities for a specific ship's engine room. When their project is just starting or very near complete, some team members are *rotated* in order to temporarily assist a machinery team having a greater workload. As shown in the second time frame, when no new project is available, an entire team is rotated to assist another. Rotating individuals to balance changing workloads requires managerial skill as people do not normally welcome such transfers.

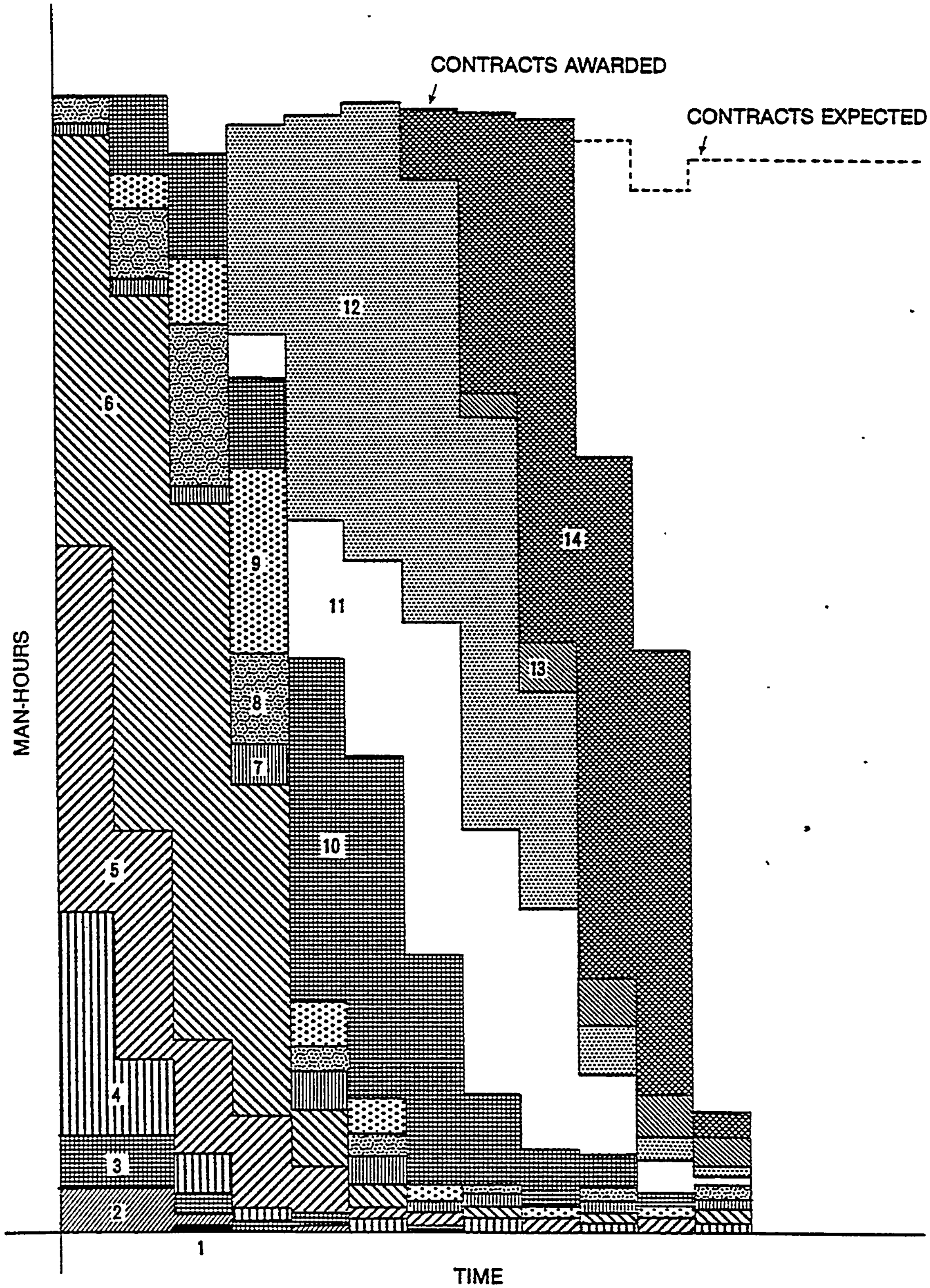

FIGURE 2-5: A typical leveled and balanced design workload for a DAME specialty, achieved by rotating team members, is shown.

2.6 *A-B-C-D Meetings*

The transfer of design end-products from one organization to another is marked by formal meetings as shown in Figure 2-6. Agendas are for the most part standardized and typically address for the

- *A-meeting* - proposed or actual contract matters, specifications, cost, budget key events schedule, etc.,

- *B-meeting* - schedule, technical specifications, budget control list, lines, owner preferences, material list and purchase specifications for major items, drawings such as general arrangement, machinery arrangement, midship section, etc.,

- *C-meeting* - special design and material requirements, pallet grouping and coding, methods, detail schedule, etc., and for the

- *D-meeting* - guarantee items and technical, material, schedule and budget evaluations of all design phases for the purpose of improving the design system.

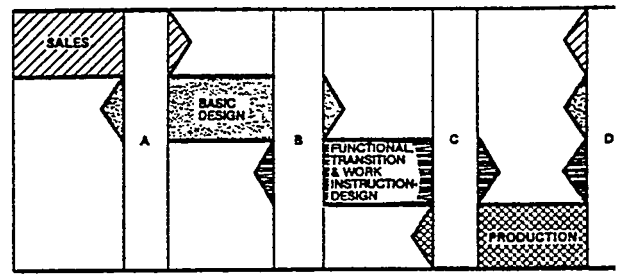

FIGURE 2-6 A-B-C-D meetings. Formal meetings arc planned and treated as essential milestones to ensure continuous communications, coordinated planning and to provide feedback.

3.0 PLANNING, SCHEDULING AND BUDGET CONTROL

The most important objective of the zone outfitting method (ZOFM) is to simplify outfit work as much as possible. In order to increase productivity every opportunity needs to be exploited for shifting oufit work to earlier stages where it is safer and easier to perform. Outfitting on-unit in a shop is more productive than outfitting on-block. Outfitting on-block, particularly for ceilings when performed down hand, is far more productive than outfitting on-board. Whether such work is effectively planned and finally incorporated in zone/area/stage work instructions, depends on how well designers and production engineers communicate with each other starting in basic design and continuing throughout the entire design process.

Where a transition is to be made to zone-oriented methods, there will be greatest impact on designers because they will have to:

- acquire understanding of production processes in terms of zone/area/stage,
- participate in devising building strategies for which production engineers have lead responsibilities,
- reflect the building strategy for each ship in contract, key, yard and stage Plans as well as in similarly structured material lists, and
- develop design details zone-by-zone, regardless of systems represented, in a sequence which anticipates exactly how each Ship will be assembled.

At the same time, because it makes sense, there will be requirements for standardizing and modularizing designers' contributions to pallets.' Through such efforts, part of a diagrammatic, its corresponding portion of a composite which serves as a work instruction and a pertinent MLF, cars be adopted or adapted for future ships of different types and sizes

3.1 General Planning

Different type and size ships have many similarities. The degrees of sameness are particularly evident when outfitting comparisons are made in the context of zone/area/stage classifications. For example, many detail-design differences can be accommodated without changing the zone/area/stage classifications of a pallet. Thus, the most effective shipyards have purposely contrived pallets which are general enough to be adopted or adapted for outfitting ship after ship. That is, information and resources needed to implement many pallets are sufficiently standardized and modularized so that they can be effectively employed without changing the building strategy and without the many preliminary considerations which characterize traditional design. This capability for instant design momentum represents a tremendous competitive edge.

In some shipyards the standard and module philosophy is extended to other aspects of planning and to aspects Of scheduling, e.g., design man-hours per drawing, design man-hours per ship, drawing issue time, etc. In at least one shipyard, costs for preparing standards and modules are regarded as capital investments.

3.2 *Pre-contract and Contanct Planning*

During contract negotiations particular attention is given to unique aspects of owners' requirements. As much as possible pertinent technical matters are *negotiated* and incorporated in contracts. Potentially troublesome iterns include:

Ž special coatings,

- special regulatory requirements, and
- unique machinery, equipment etc.

Prudent managers research an owner's existing ships and prior shipbuilding experiences in order to squire some understanding of peculiar practices, pertinent personalities, etc. If an independent design firm represents the owner, the shipyard's investigation is extended accordingly. Resolving potential problems before contract award requires the three parties to simultaneously regard ship functions and shipyard productivity.

Further, designers are required to participate in planning new facilities because such installations, particularly for ships not built before, can effect the building strategies which must be incorporated in design end-products.

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1 As used herein a standard is a basic component in hardware and/or a group of information in software that is not changed regardless of its employment. A *module* is a formation of optional components and/or information which could include standards, made to fit its employment. Per "Standardization and Modularization in Shipbuilding" by Y. Ichinose of IHI Marine Technology, Inc. for the Shipbuilding Short Course, The University of Michigan, 27-31 October 1980.

3.3 *Design scheduling*

Scheduling objectives for design and material definition, as shown in Figure 3-1, are

- drawing-issue timing commensurate with material lead times and production schedules,
- design man-hour controI commensurate with a man-hour budget, and
- material-quantity control commensurate with a material budget.

A *shipbuilding master schedule* provides dates for fabrication start, keel keel laying, launching and delivery for all ships contracted and/or expected to be built during some reasonable period. Some shipyards which have reduced the period between start fabrication and delivery to less than nine months and use a single building berth, employ a shipbuilding master schedule in bar-chart form encompassing at least two and one-half years.

As shown in Figure 3-2, a *design department master schedule is* derived from the shipbuilding master schedule and is the control mechanism for a sequence of other design schedules These control the design work for specific ships and the efforts of each of the DAME outfitting design groups.

3.3.1 *Design Deportment Master Schedule*

A useful format for a design department master schedule is illustrated in Figure 3-3. All ships in the order book are addressed plus those for which orders are expected. The format is a combination OR

- a Gantt-chart representation of the shipbuilding master schedule showing keel laying, launching and delivery dates for each ship,
- S-curves, each of which shows the accumulated design man-hours estimated for each ship, and
- a plot of the total estimated design man-hours required per month.

The latter is guidance for leveling and balancing the design workload as described in Part 2.5. It serves also to indicate if and when additional design projects can be undertaken and to predict need for overtime and/or subcontractor man-hours.

In order to support preparation of a useful design department master scheduie, the following historical files must be accurately maintained

- design man-hours per typical ship, by ship type/deadweight (design man-hours per ship are adjusted to account for atypical features), and
- design man-hours available per month.

3.3.2 *Design Group Master Schedules*

Within controls invoked by the design department master schedule and using the same logic and format, each of the DAME groups prepares a design group master schedule. This presentation enables a group manager to predict manpower shortages or surpluses. With such guidance, plans are made for manpower transfers, overtime and/or subcontracting in order to level and balance the workload imposed on each group by the design requirements for all ships.

The design group master schedules together with the design department master schedule serve for planning the outfitting design workload for all ships on, or expected to be on, order. This combination of schedules comprises a significant part of the design strategy to be implemented upon each contract award. Upon receiving a set of contract plans and specifications the ship design department and each group then prepare the additional schedules shown in Figure 3-2 which address the specific ship to be built.

3.3.3 *Ship Design Master Schedule*

A ship design master schedule is made by integrating the production schedules for outfitting work with the design workload imposed by the contract plans and specifications for a specific ship. As shown in typical bar-chart format in Figure 3-4, a ship design master schedule indicates starting and other significant dates and durations assigned related to the preparation of such documents as:

- diagrammatics,
- composite arrangements,
- purchase specifications,
- fitting drawings,
- component manufacturing drawings, and
- material lists (NILS, MLF, MLP and MIX).

The following inputs from production people are essential for preparation of the ship design master schedule:

- outfitting milestone schedule, and
- hull fabrication start date.

3.3.4 *Ship Design Group Schedules*

As exemplified in Figure 3-5, each ship design group schedule consists of separate parts for the key and yard plan efforts and is in accordance with the ship design master schedule. It is further broken down by:

- milestones for
  - start and completion dates,
  - interface meetings with other design sections and groups,
  - MLS completions, and
  - forwarding dates for owner and regulatory approvals, and
- time lirnits for issue dates.

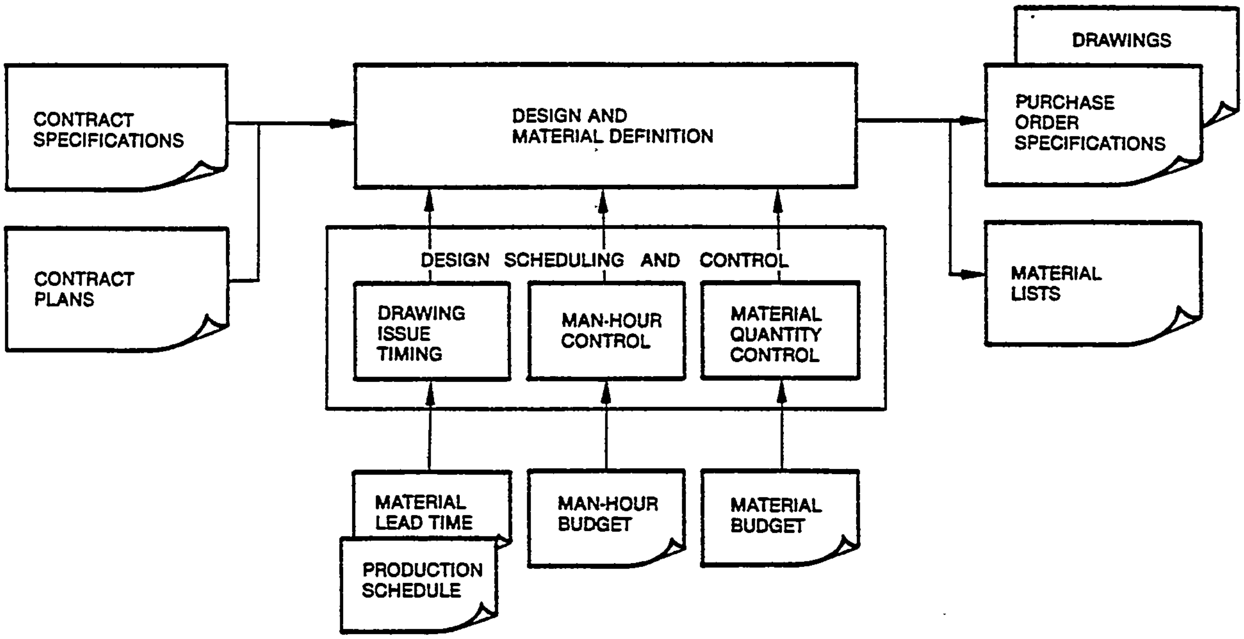


FIGURE 3-1: Ship Design Department managerial control relative to inputs, references and outputs.

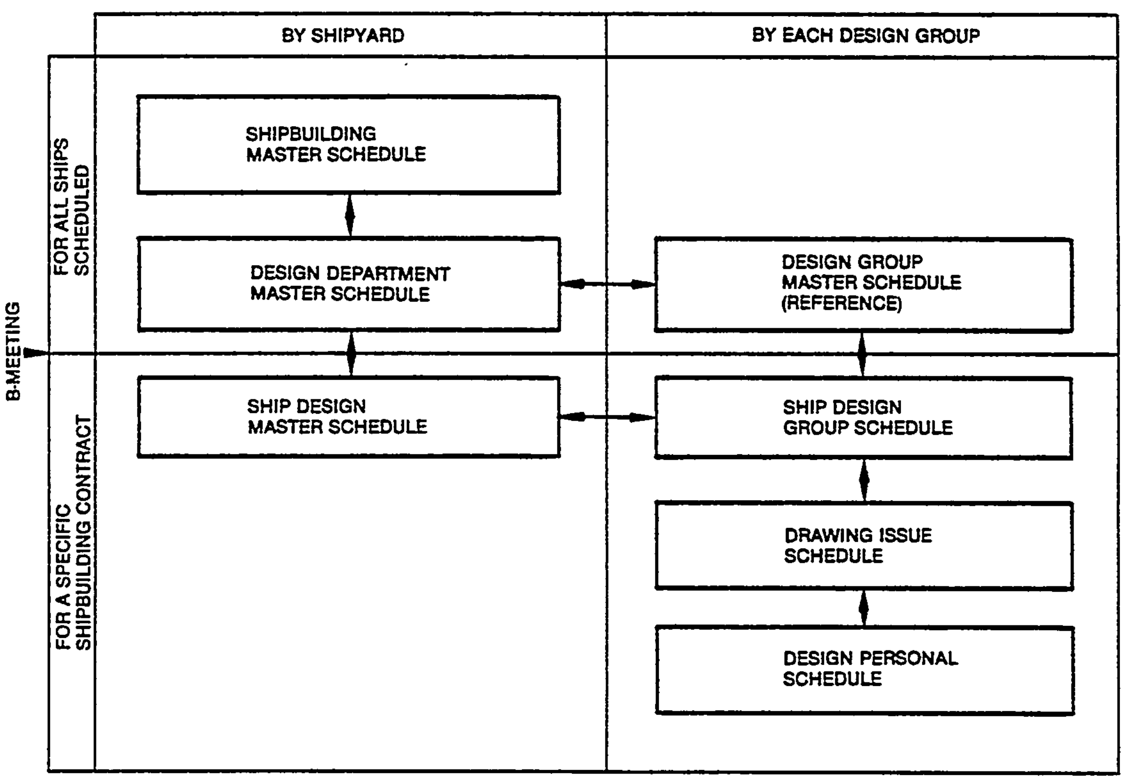


FIGURE 3-2: Design scheduling sequence.

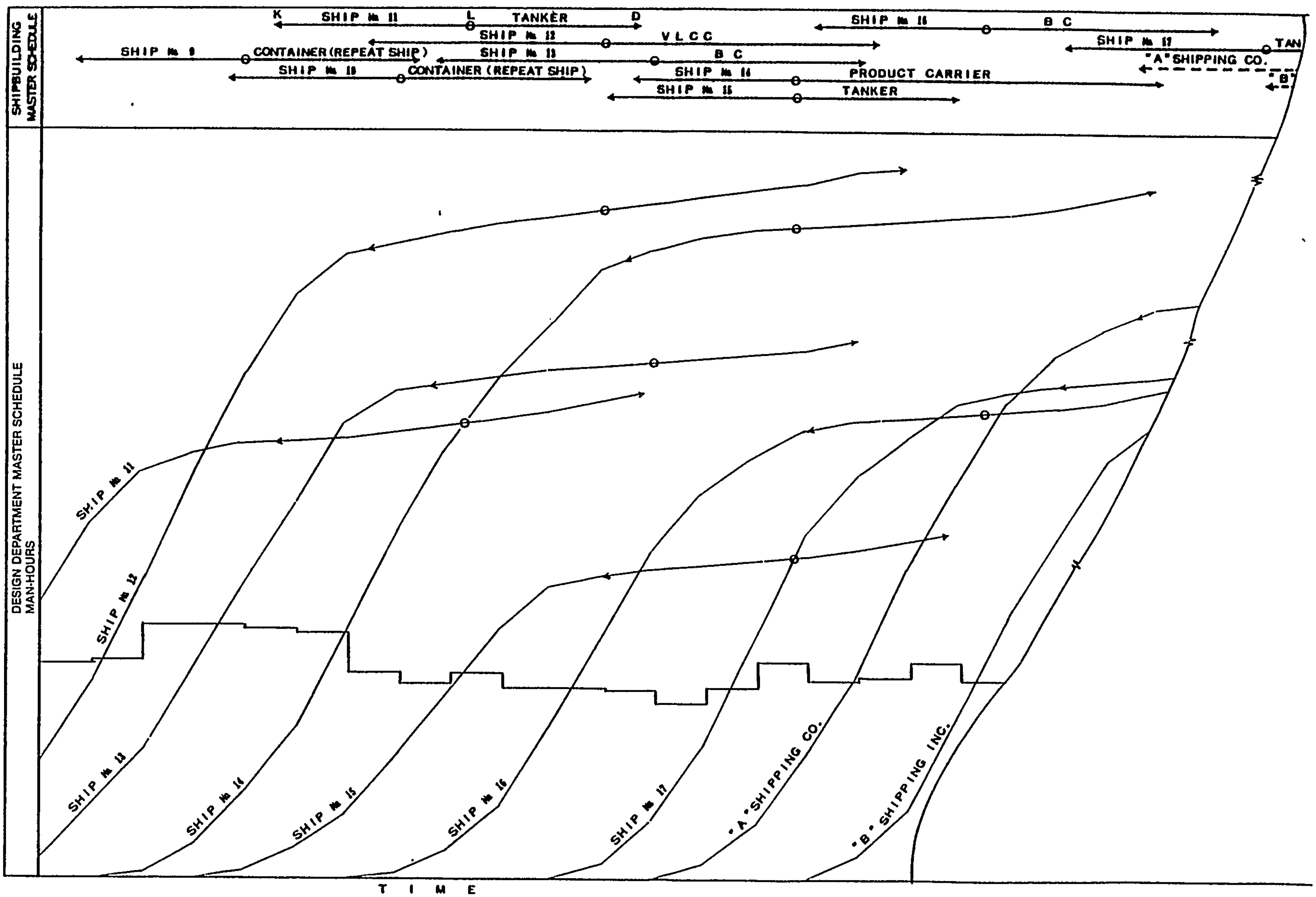


FIGURE 3-3: Design Department Master Schedule relative to a Shipbuilding Master Schedule.

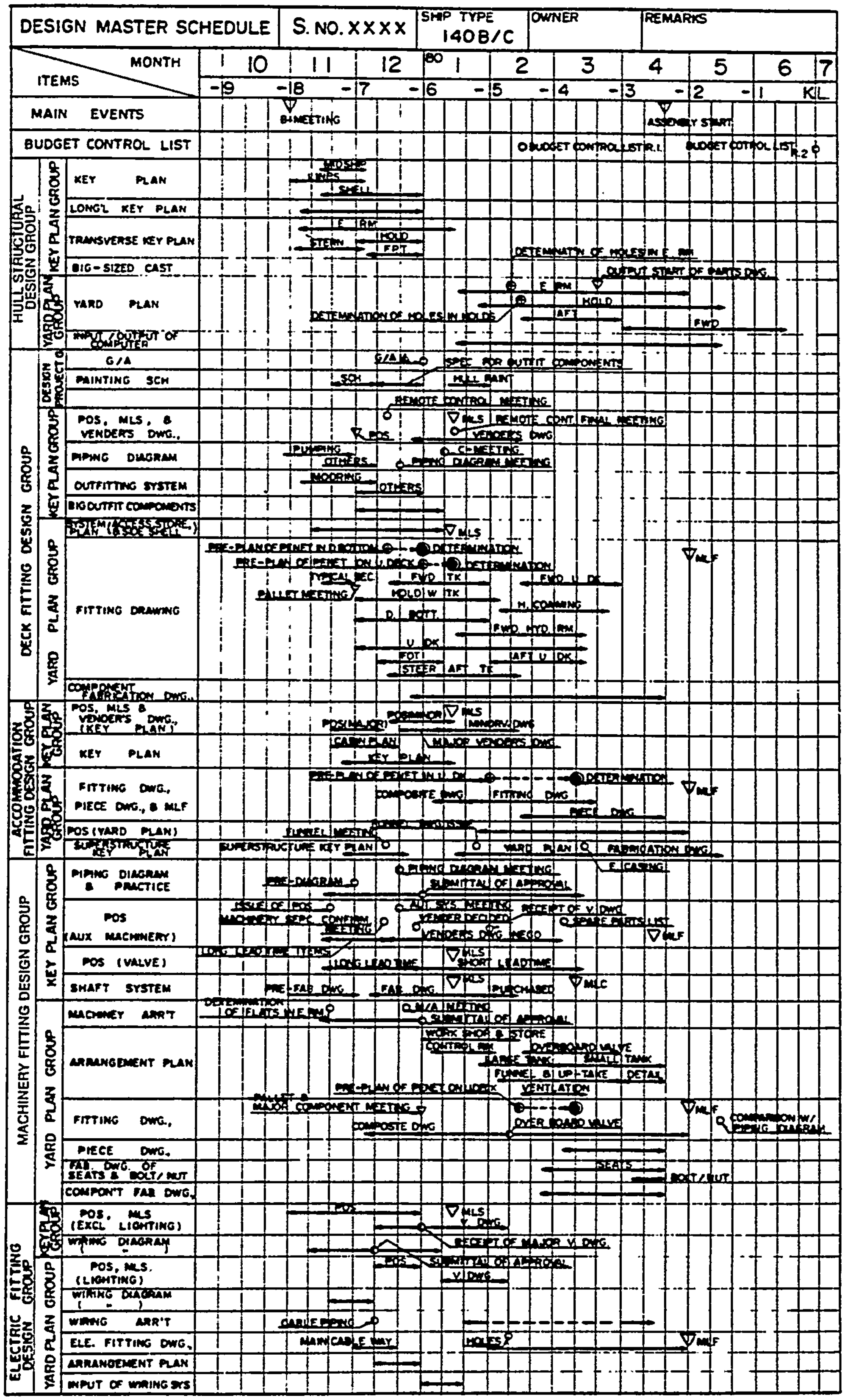


FIGURE 3-4: Ship Design Master Schedule.

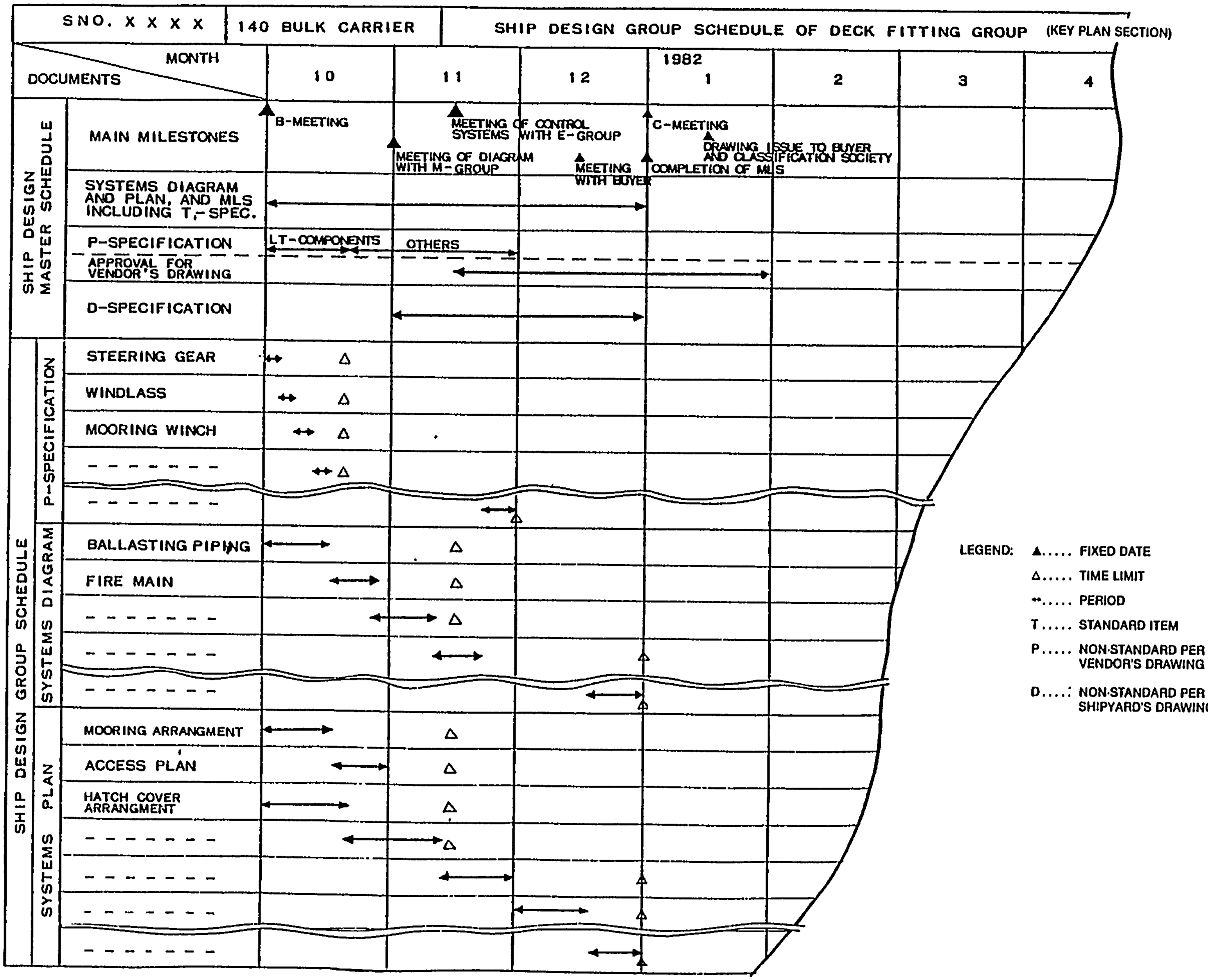


FIGURE 3-5: Ship Design Group Schedule for the Deck Fitting Design Group (Key Plan Section).

Each ship design group schedule is necessarily based on given material lead-times and production schedules. Special emphasis is applied for early scheduling of prerequisites for long lead-time items such as:

- purchase specifications for the main engine, auxiliary machinery, etc., that can be defined from the contract specifications,

- system diagrammatic and plans which specify castings, e.g., anchor, hawse pipe, etc., and

- system diagrammatic and plans which define special fitting such as a cargo-oil piping diagrammatic and mooring arrangement.

3.3.5 *Drawing Issue Scheduler*

Each DAME outfitting group makes a drawing issue schedule in separate parts for key, yard and stage plans needed for a specific ship as shown in Figure 3-6. Purchase specifications and vendor-drawing receivals and returns (after approvals) are included. The issue schedules are employed by engineers-in-charge to monitor and control design progress and completions per ship and for reporting to group managers. A booklet made up of all drawing issue schedules is sometimes used to record authorized distributions and receipts for each drawing issue, purchase specification, etc.

3.3.6 *Design Personal Schedules*

Design personal schedules are prepared strictly in accordance with drawing issue schedules in order to faithfully incorporate issue dates, budgeted man-hours, etc., for each drawing. Further, they identify and serve the specific persons and engineers-in-charge having responsibilities per drawing as in the example shown in Figure 3-7.

This last of the schedule hierarchy presented in Figure 3-2, completes the description of monitoring and controlling drawing issues in three managerial levels, i.e., by:

- the department manager with the design ship master schedule,

- each group manager with a design ship group schedule, and

- each engineer-in-charge with a drawing issue schedule and a design personal schedule.

Besides checking progress of drawing preparation, tracking is performed for:

- issue and receipt of drawings processed for owner and regulatory approvals, and

- receipt and return of vendor specifications processed for shipyard approval.

3.4 *Man-hour Budget Determination System and Control*

Statistical analysis of man-hour expenditures for past ship designs is the best basis for estimating design man-hour costs for a contemplated ship. However, such data cannot be usefully classified unless allowances are made for special specification requirements. *ln* one approach, man-hour expenditures for each DAME @oup for various ships previously designed, are plotted with some allowable distribution by size (deadweight) and by Ship type. Expenditures Which differ significantly from the average curves are analyzed until the reasons for the differences are identified and classified. Each *reason* classification is then assigned a value in terms of rnan-hours or a percentage of the average manhours by *Ship size* and type.

When a contract is awarded, the design department manager uses the historical data so processed for guidance in determining a proposed budget for allocating man-hours to each DAME group. Separately, each group manager maintains a history of *normal* man-hour costs in terms of pertinent indices, e.g., design man-hours per electric-cable unit-length, per piping unit-length, per unit-area of decks in living areas, etc. The parameters so derived are also used to estimate the workload imposed by a ship design requirement. When these estimates differ from the proposed budget allocations, the department and group managers reconcile the differences before the design man-hour budget is issued.

ML (A)

S No.

No.	DRAWING No.	TITLE	APPR OWNER	APPR CLASS	FINAL DWG	ISSUE DATE ORIG.	RIV. A	RIV. B	RIV. C	DRAWING ISSUE SCHEDULE (MONTH) -10	-9	-8	-7	-6	-5	-4	-3	-2	-1	K	STANDARD MAN-HOUR
	K2720131	Life Saving Plan										O									20
	K2830131	Ventilation Diagram (Accom.)										O									80
	K2900131	Piping Diagram (Accom.)										O									50
	K3500131	Cabin Plan									O										250
	K3400331	Joiner Work										O									30
	K3500332	Key List										O									20

FIGURE 3-6: Drawing Issue Schedule.

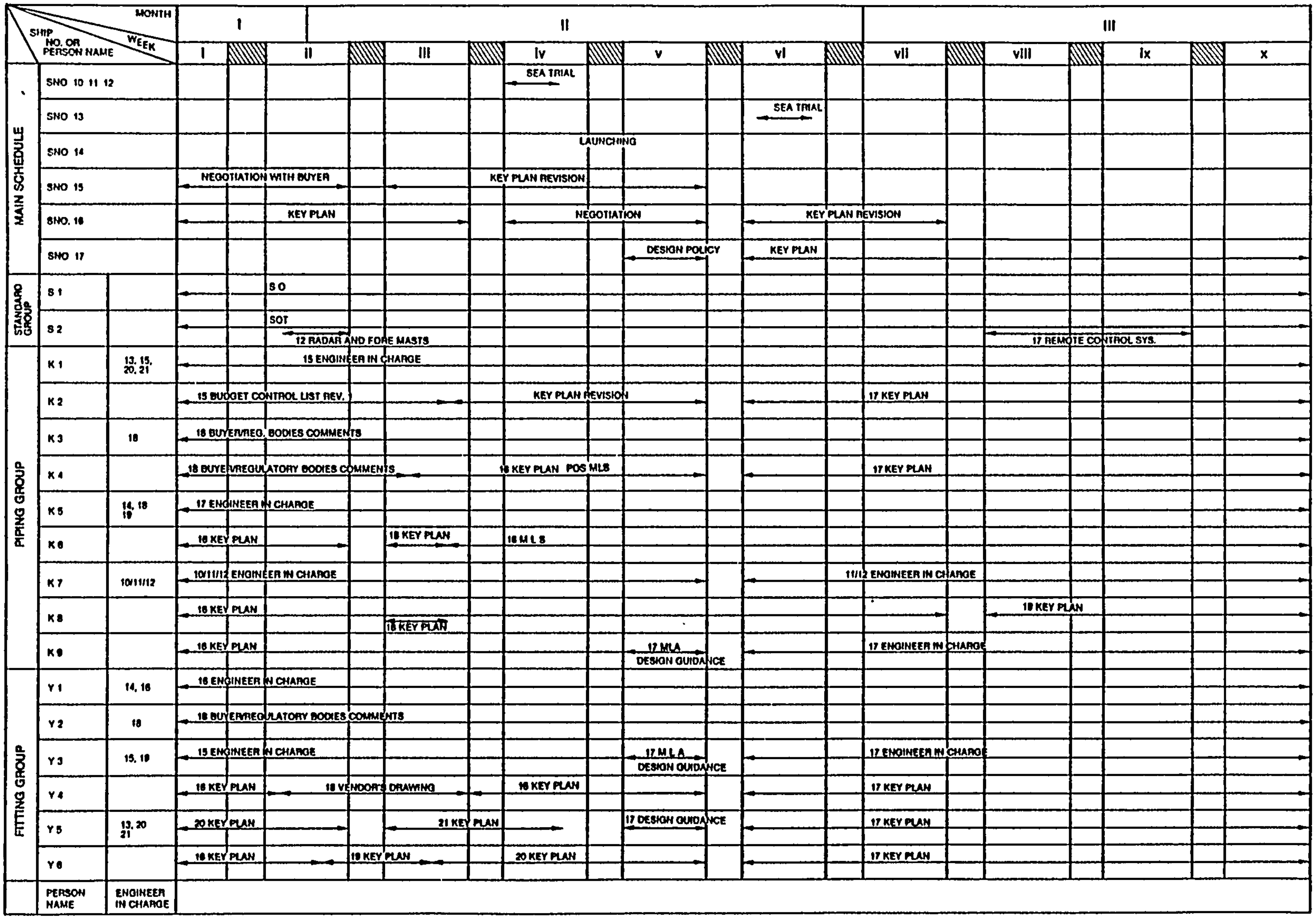


FIGURE 3-7: Design Personal Schedule for the Deck Fitting Design Group (Key Plan Section).

When man-hour budgets are assigned, each group manager is responsible for controlling the rate of man-hour expenditures. Before design work starts, each group manager plans expenditures relative to time in accordance with an S-curve. If a significant departure or trend away from the S-curve is noted during monthly entries of actual expenditures, as in Figure 3-8, the cause is identified and manpower shifts are made accordingly.

This type of tracking is not sufficient for progressing as it yields only indication of *apparent* progress. *Real* progress is monitored by check off of completions on schedules such as for drawing and purchase-specification issues and vendor-drawing approvals.

3.5 *Budget Control List*

During basic design, all material needs for each ship are exactly defined or estimated by total weight per material famiIy or cost code. This compilation for a ship is the *original budget-control list and* is one of the documents formally presented by the basic design organization during the B-meeting.

The list is employed as a *budget in every sense* of the word. It is used to control the subsequent design efforts and the production effort so that additional material requirements cannot be added without justifications and specific approvals. By employing parameters derived from past normal performances which relate fitting man-hours to weights, the list becomes a working budget for both material and man-hour expenditures. Thus the budget-control list is a significant mechanism for controlling the cost of an entire shipbuilding project.[2]

During key plan preparation, the budgeted material is allocated by system, i.e., material lists by system (NILS) are prepared which more exactly define material needs. Items which can be counted from system plans (such as for a mooring system) and diagrammatic, are indicated by weight and piece. Items which cannot be counted are listed by total estimated weight per material family or cost code. This refined knowledge is substituted so as to produce the *first revision* to the budget-control list.

When material quantities exceed the budget-control list prepared during basic design, the needs for the differences are examined. When confined, both increases and decreases are incorporated in a first revision to the budget-control list which becomes:

- the material and man-hour budget for control of there-maining shipbuilding effort, and
- feedback which basic designers employ to improve their material definition techniques.

The first revision to the budget-control list is just as important as key plans for specifying and controlling the stage plan effort.

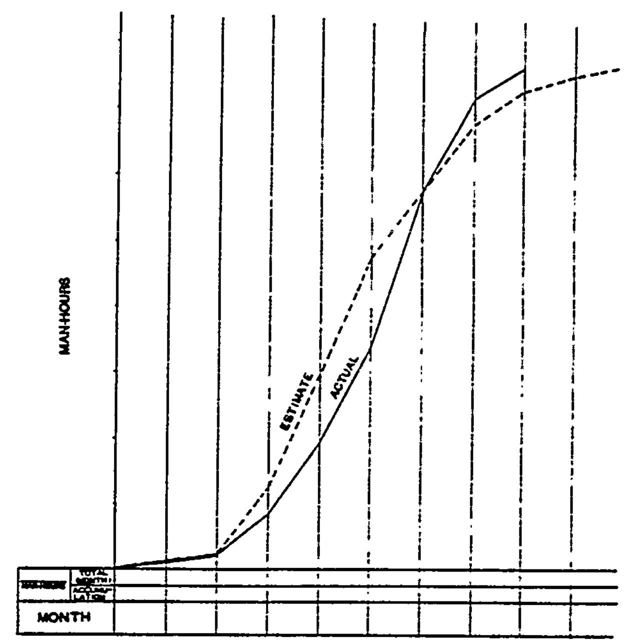


FIGURE 3-8: **Man-hour Control Curve.**

During the preparation of stage plans, material lists are prepared to match fitting work instructions (MLF) and manufacturing work instructions (MLP and MLC). Quantities are indicated by piece and/or weight per material item in detaiI for *all* materials. Special effort is made to stay within the material quantity limits imposed by the first revision to the budget-control list. Again, needs for differences are examined and when confined, both increases and decreases are incorporated in a *second* revision to the budget control list. Thus, each revision of the budget control list with progress of design development

- facilitates monitoring both material and man-hour costs for a current shipbuilding project, and
- is feedback to guide predecessor functionaries for work on the next shipbuilding project.

Upon completion of the shipbuilding effort, the second revision is replaced by a list of actual costs which is more accurate such feedback. No longer do designers specify additional material, *defacto additional work,* without limit.

[2] A senior manager in the world's foremost shipbuilding industry said "In Japan we have to control material because we cannot control peopIe." Y. Mikarni to L.D. Chirillo, June 1980.

4.0 DESIGN PHASES AFTER BASIC DESIGN

In one shipbuilding firm which has a highly developed zone-oriented shipbuilding system, basic design is wr-forrned by a headquarters organization which serves more than one shipyard. During basic design, production engineers from the designated shipyard simultaneously perform *basic planning* which documents the building strategy that is to be reflected in the developing contract plans. This effort includes predefinition of hull blocks and pre-straking of the shell in order to facilitate zone outfitting. A B-meeting marks the end of basic design by formal transfer of contract plans and purchase specifications for major items, such as a main engine, to the yard's ship design department. There the design *is* further developed on key, yard and stage plans during functional, transition and work-instruction design respectively.

4.1 *Functional Design*

The objectives to be achieved during the functional design phase, as shown in Figure 4-1, include

- display of all ship's functions on system diagrammatic and plans,
- definition of *all* outfit materials required per system including raw materials (e.g., pipe, structural angle iron and electric cable),
- issue of the first revision of the budget control list which advises all concerned of updated material quantities and weights,
- preparation of purchase specifications not prepared by basic designers,
- preparation of manufacturing drawings for long-lead time items identified during functional design,
- obtaining owner and regulatory approvals, and
- approving vendors' drawings.

4.1.1 System Diagrammatic and Plans (Key Plans)

During preparation of key plans an immediate concern is to optimize ship's functions consistent with regard for operational and maintenance aspects. A.typical diagrammatic and system plan are shown in Figures 4-2 and 4-3 respectively.

Each diagrammatic

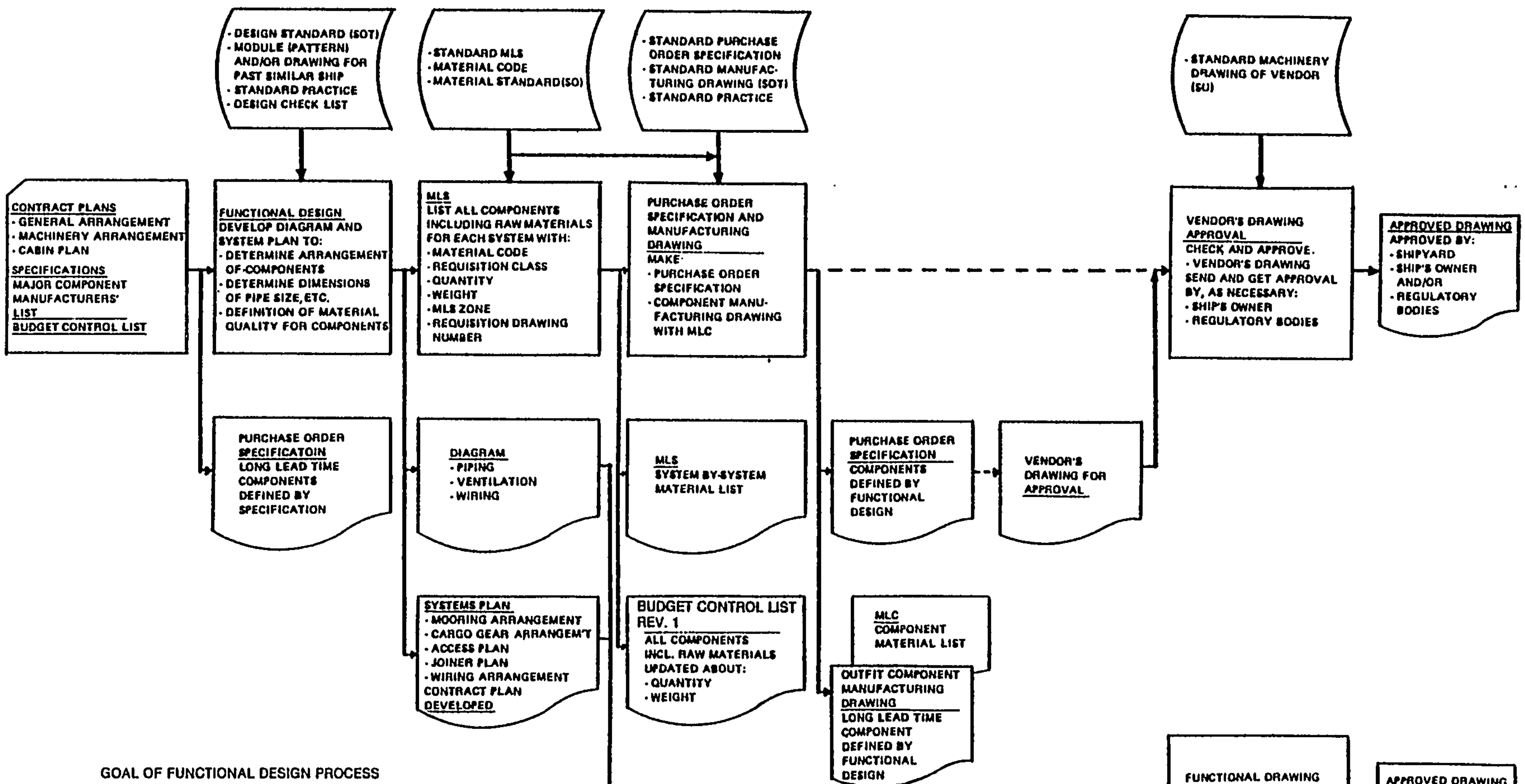
- shows subditilons, except for electrical systems, to the extent that it was prepared by more than one DAME group, and
- is further subdivided, including electrical systems, by each DAME group into about 3 to 7 *material ordering zones (see* Figure 4-4 which reflect the erection sequence so that purchasing and manufacturing orders for LT materials can be placed before completion of the remaining design phases.'

On system plans:

- distributive systems (piping, ventilation ducts, walkways, electric cable, etc.) are sized,
- the operational aspects of each system is well balanced,
- locations are shown for fittings, called S-components, whose exact positions are to be owner and/or regulator approved, and
- general system instructions are incorporated.

Other than the subdivision of diagrammatics by DAME specialty and by material ordering zones and by locating S-components on system plans, functional designers defer locating fittings to a later design phase. After system diagrammatic and system plans are revised commensurate with owner and regulator approval comments, they are key inputs for guiding the next design phase.

Parts 2.1 and 4.5 of the National Shipbuilding Research Program publication "Outfit Planning - December 1979" refer.



GOAL OF FUNCTIONAL DESIGN PROCESS

- TO DEVELOP SYSTEM-ORIENTED FUNCTIONAL DESIGN TO SATISFY SPECIFIED SYSTEM FUNCTIONS.
- TO ISSUE DOCUMENTS IN TIME TO MEET SCHEDULES OF THE SUBSEQUENT DESIGN PROCESSES, MATERIAL PROCUREMENT, MANUFACTURING AND FITTING.
- TO DEFINE MATERIALS WITH REGARD FOR MAINTAINING THE MATERIAL BUDGET.
- TO OBTAIN APPROVAL OF SHIP'S OWNER AND/OR REGULATORY BODIES ON SCHEDULE.

FIGURE 4-1: Flow of functional design reponsibilities.

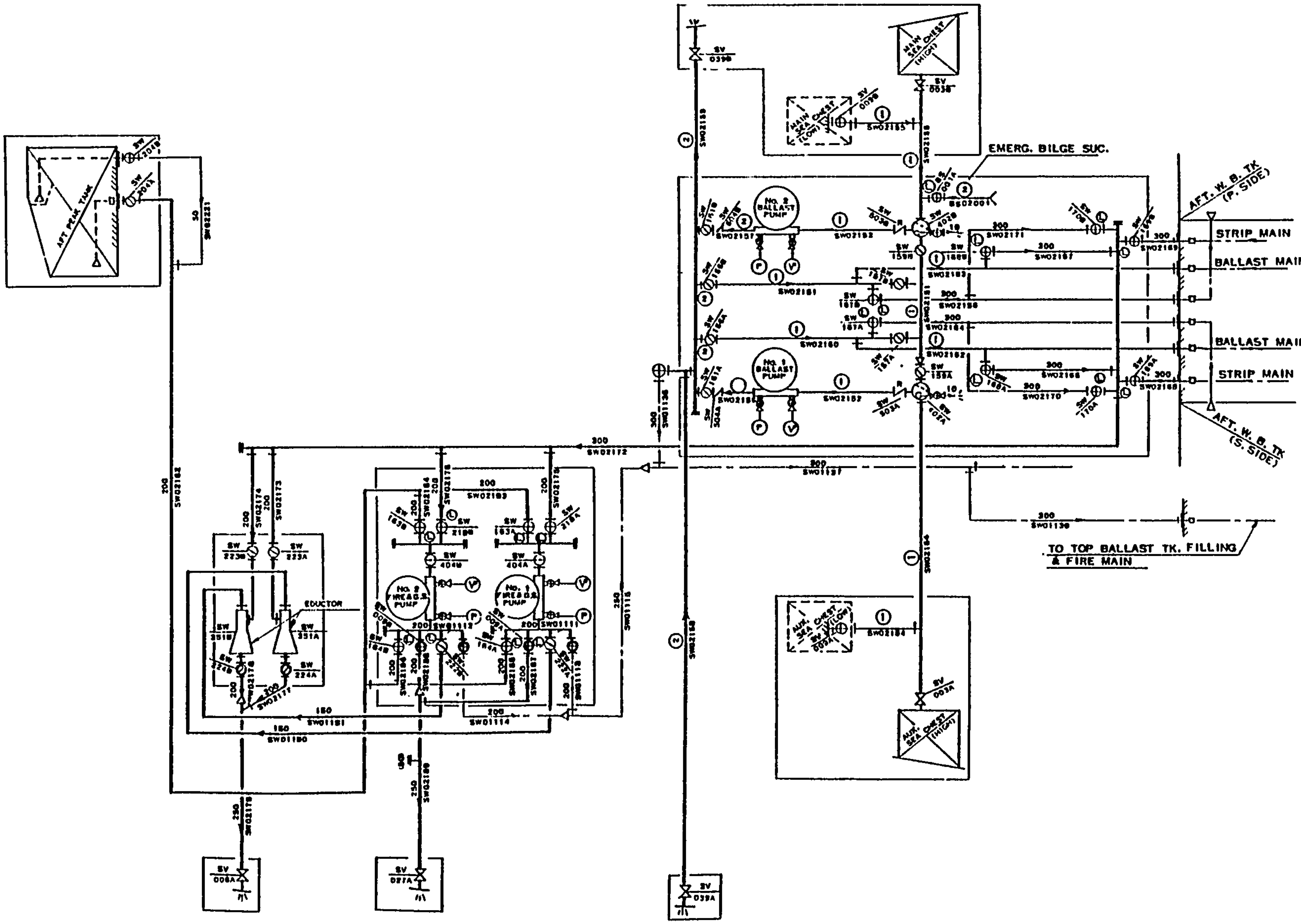


FIGURE 4-2: **Typical diagrammatic for a Sea Water Ballast System. The portions enclosed in borders are from patterns that are available for reapplication in ship after ship.**

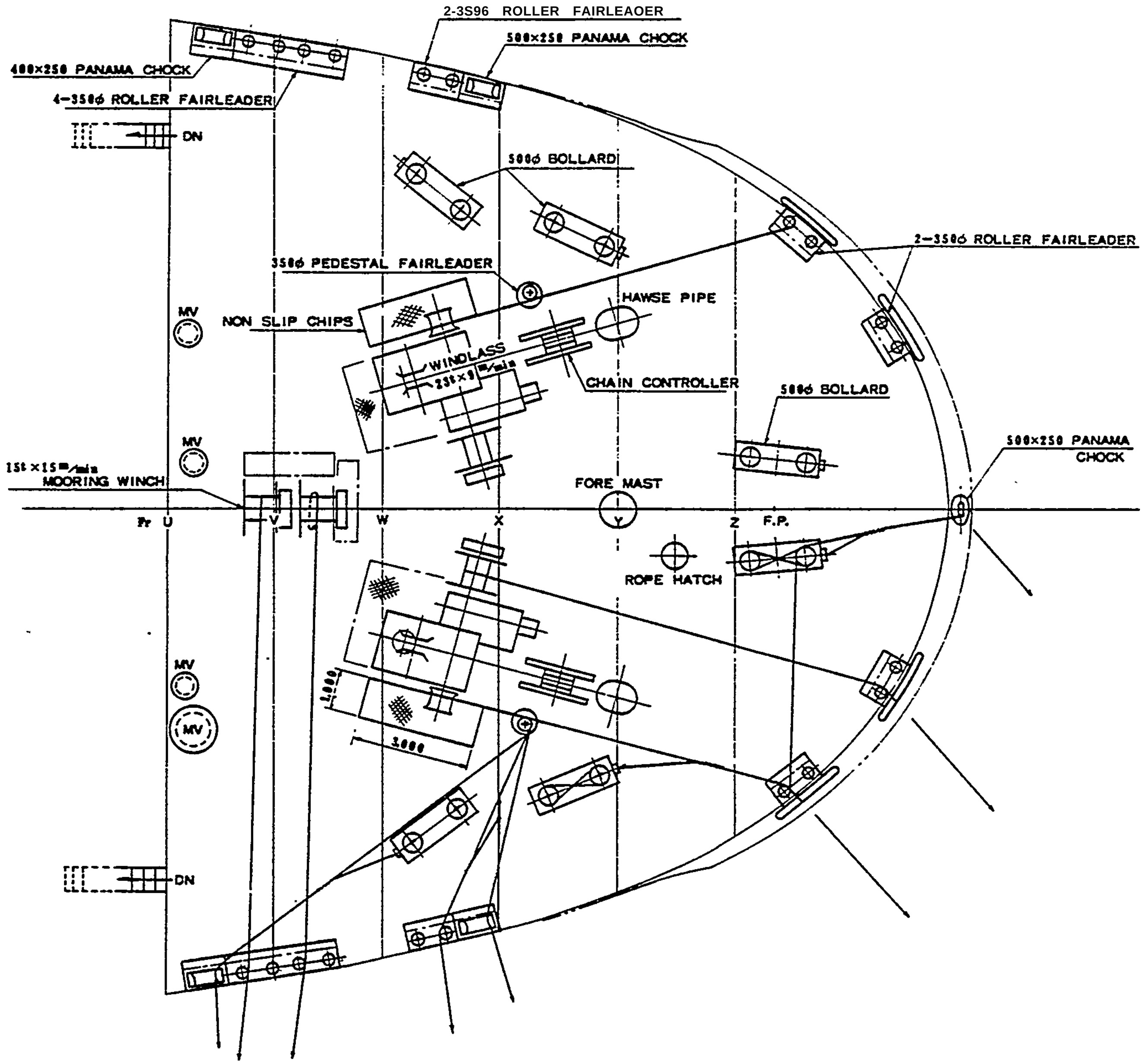


FIGURE4-3: A typical system plan for a mooring-system arrangement on a forecastle deck. ***Functional*** aspects are illustrated. A freed arrangement is dependent upon subsequent development of a hull structural plan.

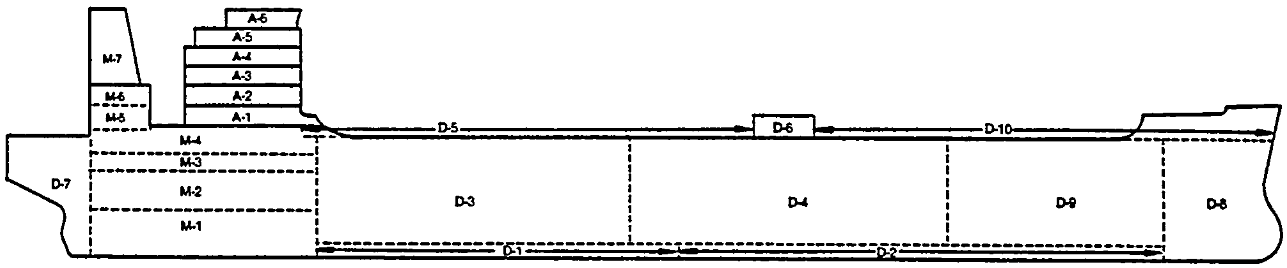


FIGURE 4-4: **Material orderings zones as defined for a relatively large and complex ship. For an average merchant ship, 3 to 7 zones each are usually sufficient for the deck, accomodation and machinery specialties. The electrical specialty usually employs the zones determined by the other specialties.**

4.1.2 *Material List by System (MLS)*

As a *major* functional design responsibility, *all* required material is tabulated by MLS for each key plan. Purchased components, fittings to be manufactured in-house or outside, and raw materials are included in the following manner:

Ž items which can be identified and *counted are listed* by full descriptions and *wet* quantities,

• items which can be identified but not counted are listed by full descriptiotts and *estimated* quantities, and

Ž remaining items are listed by total estimated weight per cost code.

Special effort is applied to finalize the definition of all long lead-time materials (LT materials) on NILS by the first or second methods noted. The definition of short lead-time materials (ST materials) can remain by total estimated weight per cost code until a subsequent design phase. However identified, ST materials are needed in MLS because MLS are the basis for updating the budget control **list.** Thus, the purposes of MLS are to:

- issue the first revision to material quantities on the budget control list for better controlling material and man-hour costs, and to
- kick off the major outfit-material procurement effort as early as possible.

MLS are delivered to the material control department where they are promptly.

- screened to identify common and LT materials,
- sequenced in accordance with dates assigned per material ordering zones (Within a material ordering zone, the need date for the first material item required is used for all materials within that zone.), and
- checked against the shipyard's inventory.

Immediately thereafter, the material requisitioning process is started.

Since MLS kick off a massive procurement effort, functional designers are responsible to insure that material descriptions include specifications and drawings as necessary for both in-house and outside procurements. Such descriptions are in accordance with material requisition and control classifications as well as material codes.

The *full description* for each material item listed in MLS includes:

Ž material code,

•piece number,

•material cost classification number,

•material listing Classification,

•parent/child sign (MLC parts and raw materials are called *children* and the item to be manufactured is a *parent.* Both are listed in MLS to insure that they are screened for common and LT materials by material controllers. The *parent sign is* needed for production, budget and cost control as well as for procurement. The *child sign is* needed for procurement only.),

- material requisition classification,
- material control classification,
- material purchasing classification,
- **weight,**
- quantity, and
- material ordering zone.

Material definition imposes a significant workload on functional designers. Employment of standard materials as much as possible is essential. Because all parties concerned, including potential suppliers, maintain up-to-date files of standard (T-specification) material descriptions, just material codes are sufficient for describing such materials on MLS. Thus, the effectiveness of a standards program is directly related to the effectiveness of functional designers.

A non-standard item that is to be manufactured in-house or outside in accordance with a shipyard drawing is called *D-specification* material. A D-specification, i.e., a drawing or other description sufficient to manufacture an item, is prepared simultaneously with its MLC.

A non-standard item that is to be manufactured in accordance with a vendor's drawing is called *P-specification* material. Functional designers participate in the vendor selection process by checking, correcting and/or approving only technical aspects of vendor proposals received in response to P-specifications.

As numerous materials are required and various categories of information are necessary for each item, computer processing is essential. Programs for maintaining the budget control lists, MLS, MLC and subsequent material documents and their relationships to each other, are the most important computer programs in shipbuilding.

The outputs of functional design which are sent to the material control group for procurement are MLS, P-specifications and D-specifications with MLC. The outputs which are needed for subsequent design development are key plans accompanied by MLS, P-specifications with approved vendors' drawings, and D-specifications with MLC.

Obviously, functional designers must be very knowledgeable of the material definition system and must be constantly mindful of the great need for just-in-time material procurement anticipating a zone-by-zone outfitting strategy. This means judicious sequencing of material definition to suit while expediting the definition of LT and P-specification materials and not getting bogged down with defining ST materials. Otherwise there can be no rapid start-up which is an indispensable competitive aspect.

4.2 *Transition Design*

Transition design, basically, is the process of transforrning system-oriented information into zone-oriented information. The end products are *yardp[ans so* named because they represent the first grouping of information to suit the way production work is organized. Thus, yard plans must be based on a preconceived *pallet list* (outfitting strategy).

The flow of transition design responsibilities is shown in Figure 4-5.

4.2.1 *Pallet Meetings*

Pallet definition that facilitates IHOP is required for transition design. Thus, a series of three pallet meetings is scheduied for the purpose of creating and refining a *pallet Iist* in terms of zone/area/stage.

The first *pallet meeting is* held just after the B-meeting. Inputs include predefintion for both blocks and pallets represented by hull construction and outfitting planning groups respectively. Each is an ad-hoc team, consisting of a few production engineers normally assigned in shops, that is assigned planning responsibilities for a specific ship. Engineers from the hull structural design and DAME groups necessarily attend.

The hull construction and outfitting production plans are explained by the respective planning groups. Designers describe block weight, fitting positions and material volume (weight and quantity) of outfit components, etc. As a consequence of such discussion block definition may be adjusted. Thus, the outputs of this meeting are final block definition and an original pallet list.

With designers participating, decisions are made concerning

- loading methods for major machinery, e.g., main engine, boiler, generator, etc.,
- fitting methods for auxiliary machinery and other components,
- fitting stages, e.g., on-unit, on-block (before and after turnover) and on-board,
- size and weight limitations, and
- final block definition (positions of erection butts and seams).

The *second pallet meeting is* held during transition design just after diagrammatic are *roughly* arranged to create *composite drafts, i.e.*, the first interrelationships of systems and zones. Design and production engineers representing the outfitting disciplines, attend. Decisions made at the meeting are based on study of the composite drafts and provide guidance to transition designers for preparing finished *composite arrangements.*

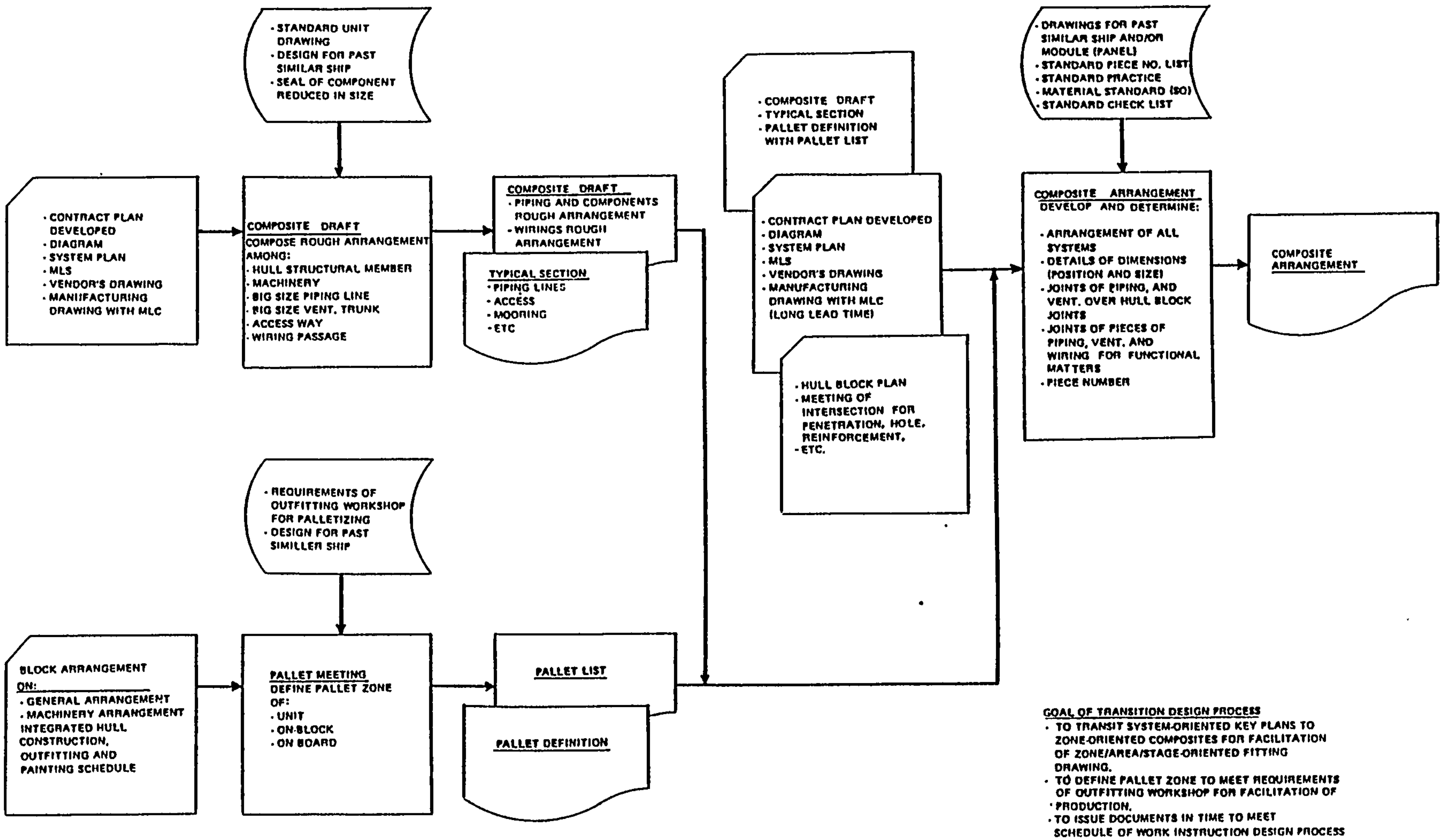


FIGURE 4-5: Flow of transition design process.

The *third pallet meeting is* held to confirm the completed composite arrangements. The production engineers in attendance are thus assured that the agreed upon outfitting strategy is faithfully incorporated before the start of work instruction design.

4.2.2 *Composite Drafts*

During transition design, systems as defined on diagrammatic, are roughly arranged as shown in Figure 4-6 in accordance with a furnished *paltet list* (outfitting strategy). Only details which impact on functional aspects and building aspects are specifically defined (e.g., locations of controls, valves and gages relative to a pump and fittings relative to erection butts and seams). Thus, the preparation of yard plans is assigned to the most experienced individuals having good command of both ship operating and shipbuilding methods.

Each composite draft incorporates quite a number of contiguous pallets so that a well-balanced fittings arrangement qart be achieved for a relatively large region by few designers. For example, attempt is made to distribute engine-room systems equally to port and starboard as well as equally on the tanktop and various engine-room flats.

The rough composites, rather quickly produced, are none-the-less arrangement requirements that less experienced designers must follow for preparing relatively finished versions, i.e., *composite arrangements. Also,* composite drafts provide the needed interfaces which permit the more laborious preparation of composite arrangements to be readily apportioned by zone to more people than could otherwise be employed, e.g., people in DAME shops or in independent design firms.

Composite drafts are usually produced for conjested arrangements as in an engine room. For less difficult regions, the system/zone interrelationship is directly established on composite arrangements. Composite drafts are also prepared by experienced designers to identify arrangement patterns, as shown in Figure 4-7, which are to be repeated during the preparation of composite arrangements. Thus, composite drafts are normally employed only during transition design.

During the preparation of composite drafts, transition designers typically consider

- for operating and maintaining a ship
  - specified systems' capacities,
  - accessibility,
  - proximity of hull structure, and
  - orientations of pipelines (e.g., needed slopes of scupper drains, elimination of U-bends, placement of bilge suctions, etc.)
- for productivity
  - how to facilitate manufacturing and fitting,
    rigidity and compactness of outfit components,
    usage of hull structural members for outfitting,
  - minimizing on-board outfitting,
    maximizing the use of straight pipe pieces to minimize bending work,
    limiting pipe bends to 90 degrees and when other bends are necessary to 45 degrees insofar as possible,
    arranging pipe lines in parallel so that they can share common pipe supports,
    avoiding arrangements which follow hull curvature,
    maximzing pipe piece lengths to minimize the number of pipe joints,
    observing weight and size limitation for outfitting on-unit and on-block (e.g., crane capacities and shopdoor sizes),
    avoiding the location of components on or near erection butts and seams,
    avoiding the location of outfit units astride erection butts and Seams-, and
    providing for adjustable pipe pieces to be fitted on board.

4.2.3 ***Composite Arrangements***

Composite arrangements portray exact positions and identities of outfit components and pipe, ventilation duct and wireway paths in accordance with composite drafts or otherwise, directly in accordance with the pallet list. Considerations include sizes and weights of fittings, nature of the work involved as well as the considerations listed for composite drafts in Part 4.2.2. Items which are defined include:

- three dirnensionaI locations of certain components, e.g., machinery, other equipment, foundations, ladders, access ways, handrails, and pipe, vent duct and electric-cable way *paths,*
- piece numbers for the separable components less those for distributive systems,
- pipe-, duct- and wiring-system codes,
- instructions for locating flanges that effect functional aspects of pipe and duct systems, e.g., flanges necessary for maintenance, and
- instructions for locating flanges relative to erection butts and Seams.

Beyond division by DAME, composite arrangements are further subdivided in accordance with a practical scheme as follows:

- **deck group**
  - forward upper deck,
  - middle upper deck,
  - after upper deck,
  - forepeak tank, and
  - cargo hold or cargo tank, (bottom, transverse bulkhead, and longitudinal bulkhead).
  - pump room (tankers only),
  - steering gear room, and
  - afterpeak tank.

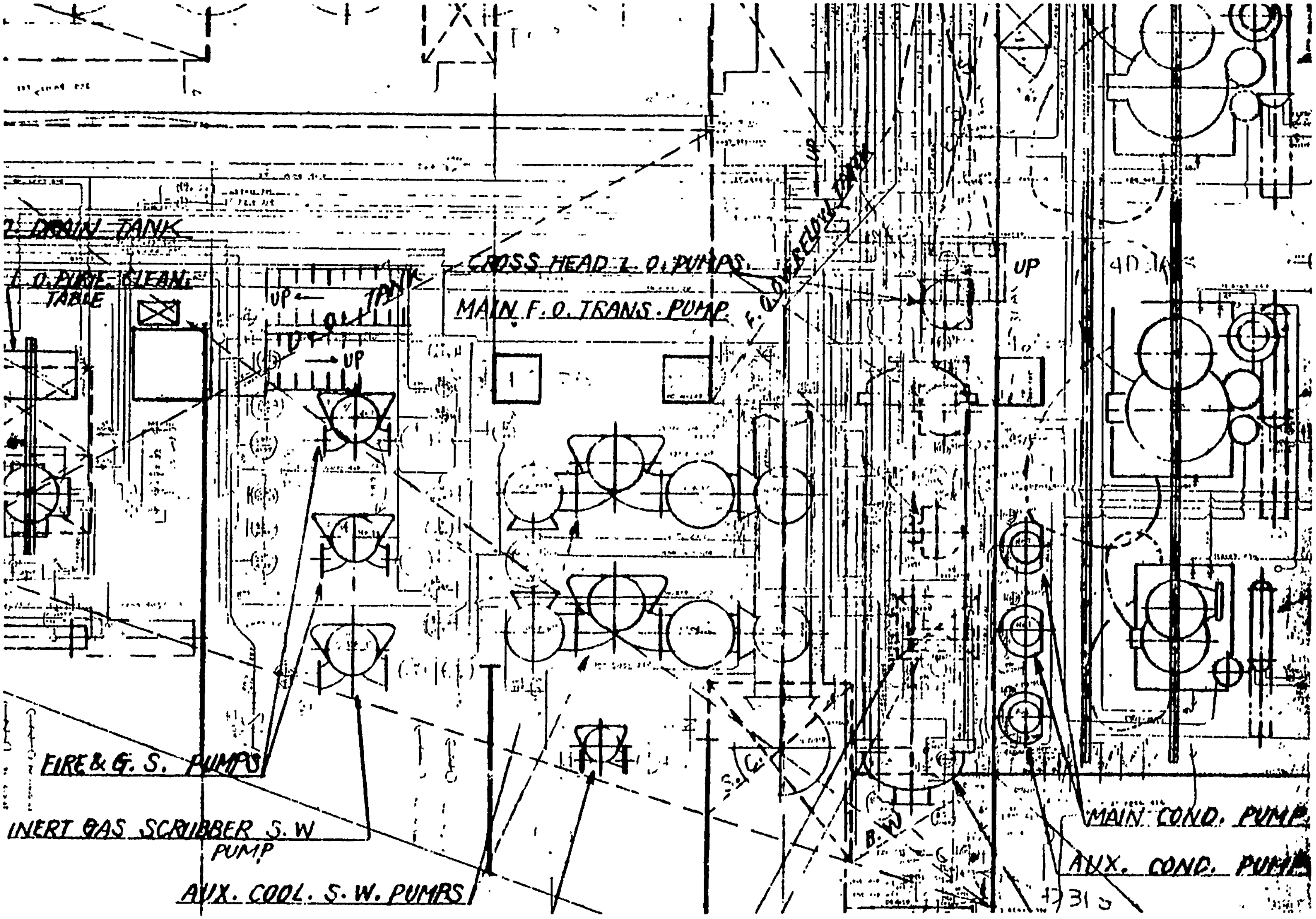


FIGURE 4-6: A typical composite draft for a relatively conjested engine room. This draft was made on a copy of the machinery arrangement, a contract plan, which anticipated that pipes were to be arranged in parallel under walkways and with bends mostly limited to 90 degrees. Prepared by people most experienced in ship operation and shipbuilding matters, composite drafts are used by others engaged in transition design to prepare smooth composite arrangements.

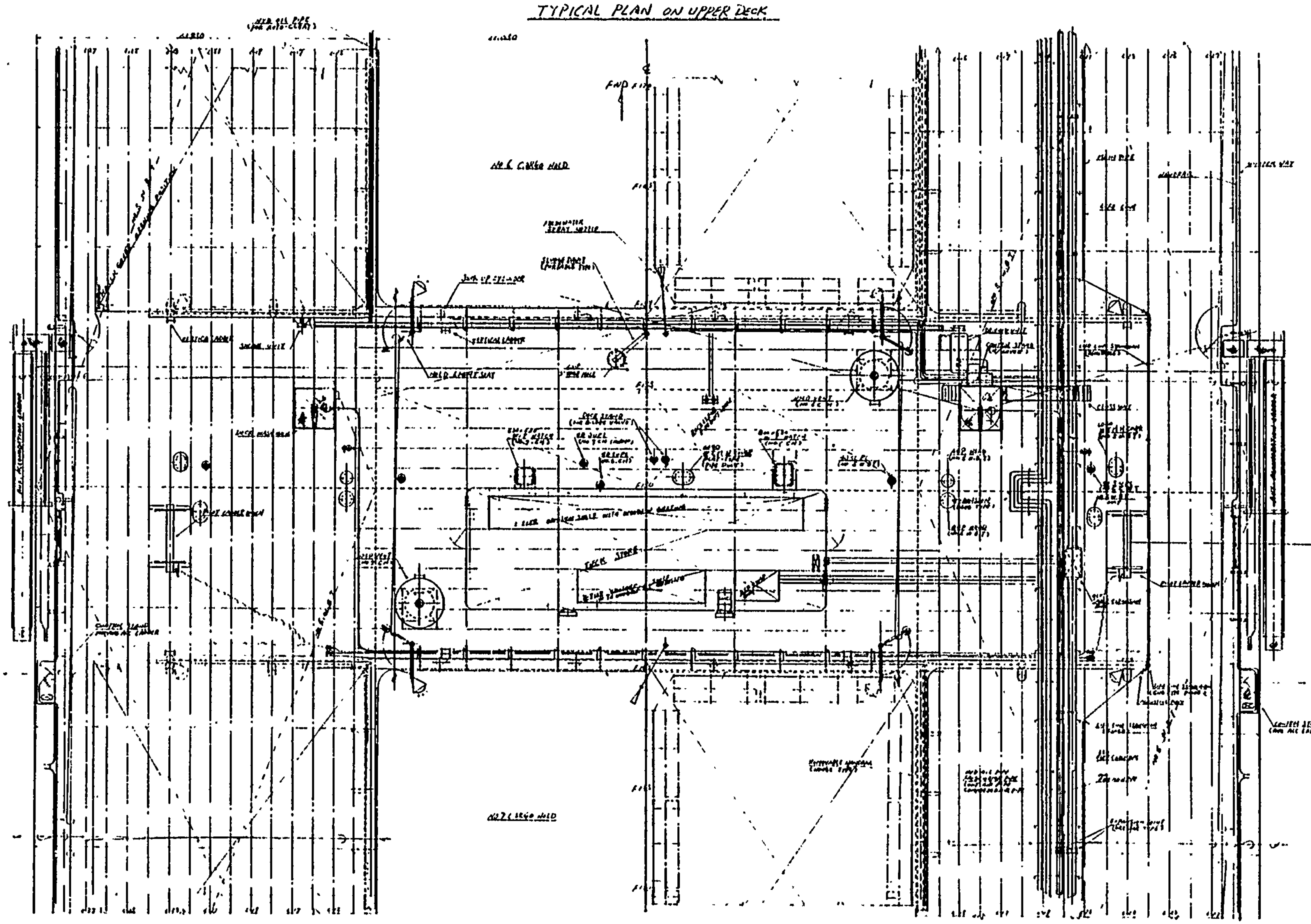


FIGURE 4-7(a): Repeatable composite draft of a typical plan for an upper deck.

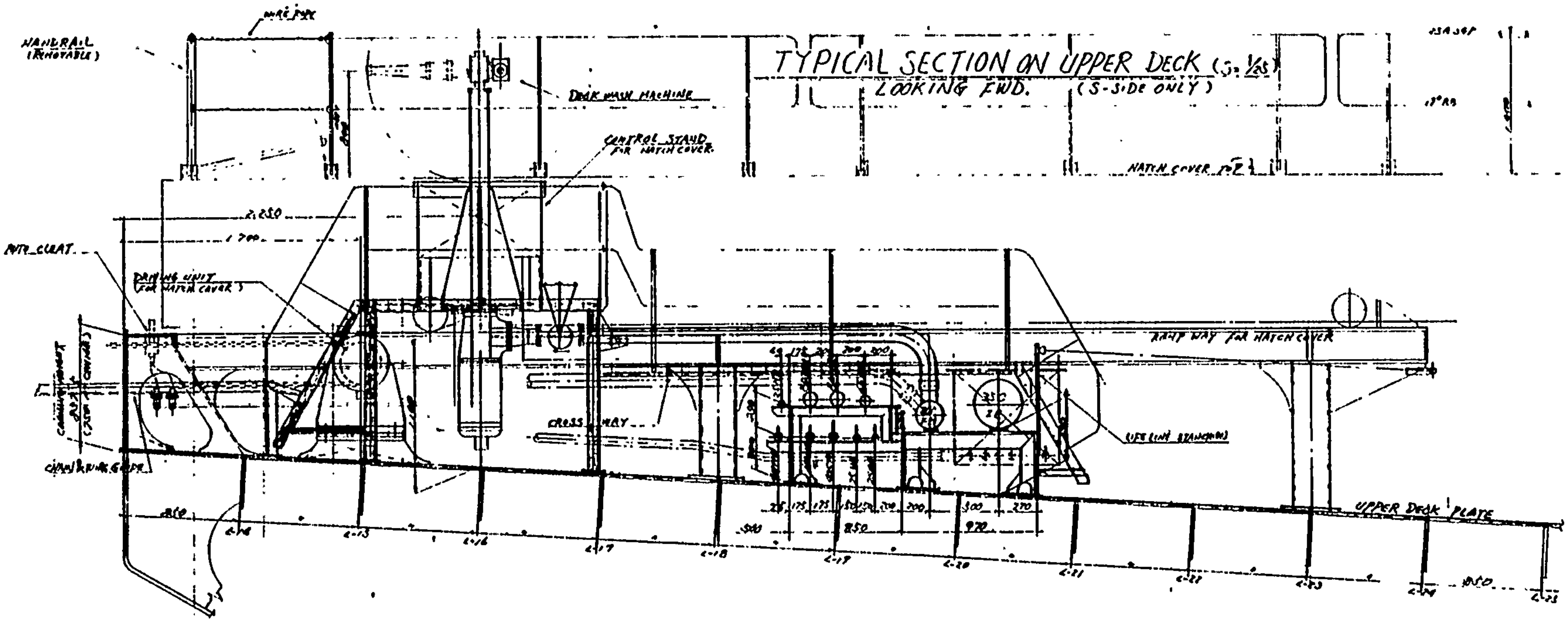


FIGURE 4-7(b): **Repeatable composite draft of an elevation for a portion of the upper deck plan shown in Figure 4-7(a).**

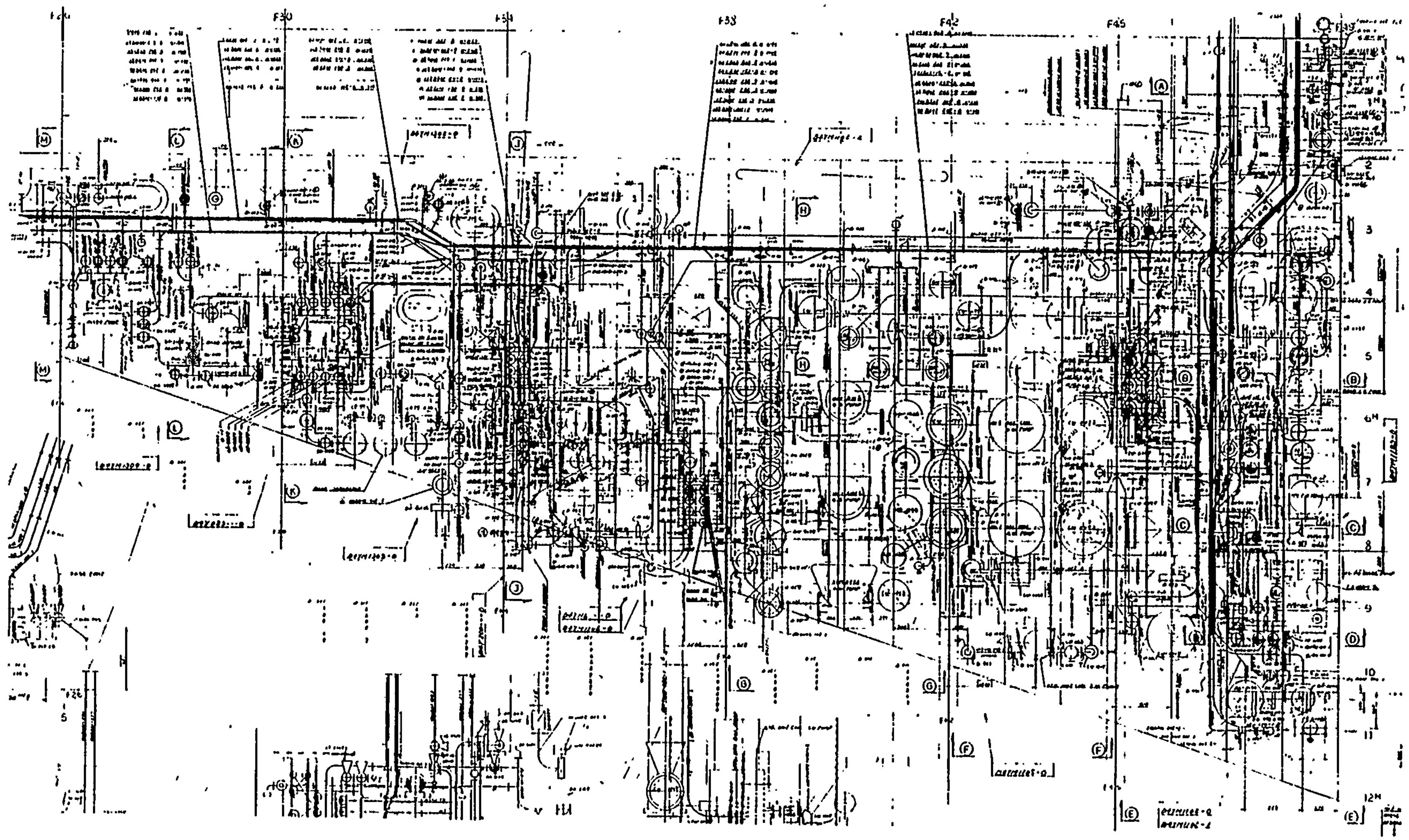


FIGURE 4-8: A typical composite arrangement for conjested zones occupied by machinery and piping on an engine-room tank top. Fitting instructions are incorporated in highly symbolized codes.

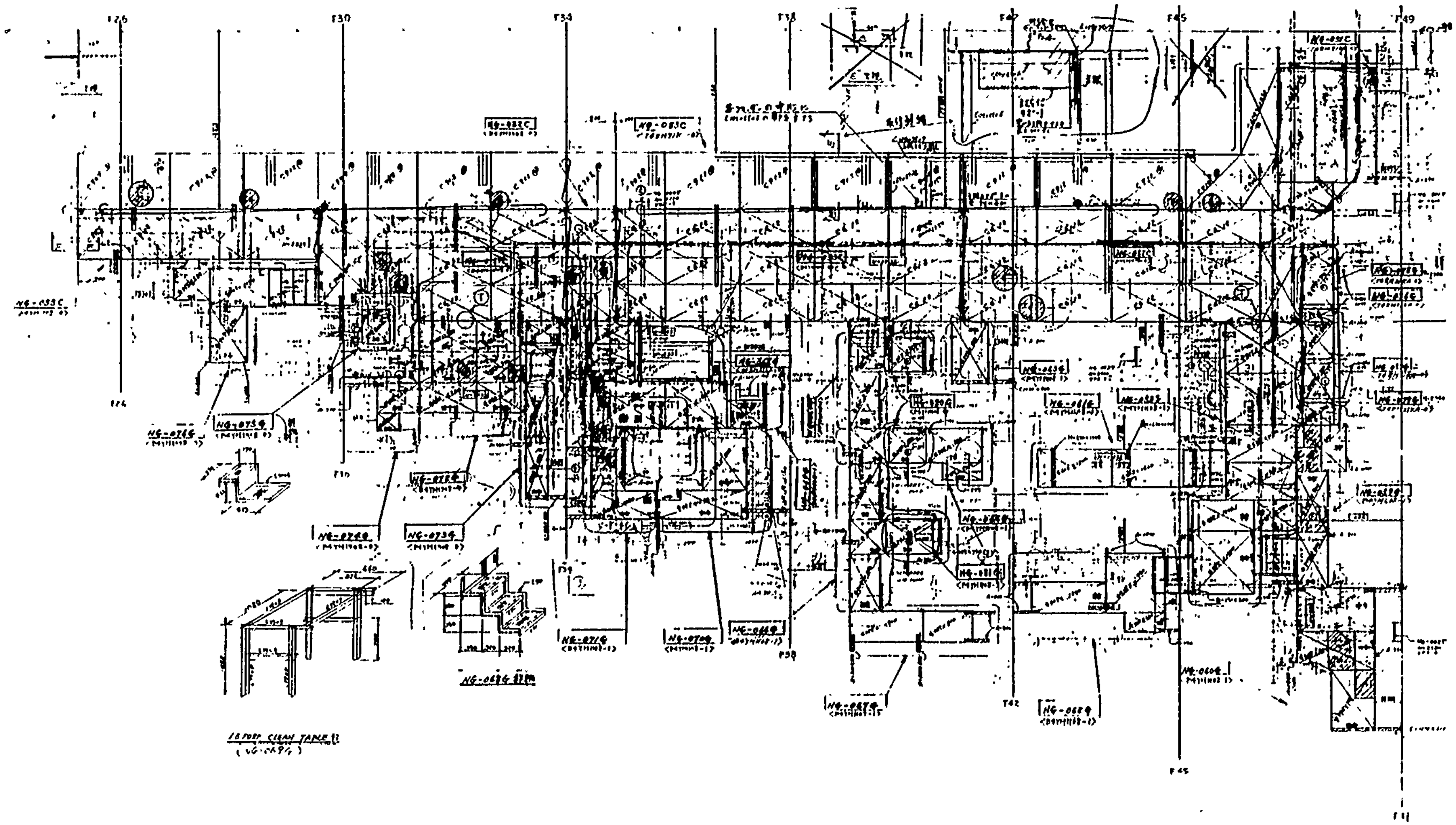


FIGURE 4-9: **A typical composite arrangement for conjested zones of floor gratings and access ways for an engine-room tank-top level. This arrangement was drafted on a light-line copy of the composite arrangement for machinery and piping shown in Figure 4-8.**

- accommodation group
  - A-deck (upper deck),
  - B-deck,
  - Cdeck,
  - Ddeck,
  - navigation bridge deck, and
  - compass bridge deck.

- machinery group (engine room, casing and fumel only)
  - tank top,
  - second deck flat,
  - third deck flat,
  - upper deck,
  - engine casing, and
  - funnel.

  Also, for the machinery space levels, the composite arrangements are separately prepared for decks and overheads.

- electric group

  The subdivisions for electrical are the same as those adopted for deck, accommodation and machinery. UsuaIly, the electric composite arrangements are drawn on light-line reproducible copies of the composite arrangements prepared by the deck, accommodation and machinery groups.

Ideally, the zone-by-zone composite arrangements would show all fittings within each zone. As such composites for conjested regions, e.g., an engine room, are difficult to prepare and decipher, they are separately produced by grouping fitting types. Groupings that have been found to" be practical are

- machinery and piping as shown in Figure 4-8,
- access ways including ladders and floor plates as shown in Figure 4-9, and
- ventilation ducts.

A useful scheme for combining fitting types to be shown on. composite arrangements is illustrated in Figure 4-10. In shipyards where there is significant development of standard symbols, descriptions, components, etc., some composite arrangements are simple enough to be used directly as work instructions.

A typicaI composite arrangement prepared by a deck outfitting design group is shown in Figure 4-11.

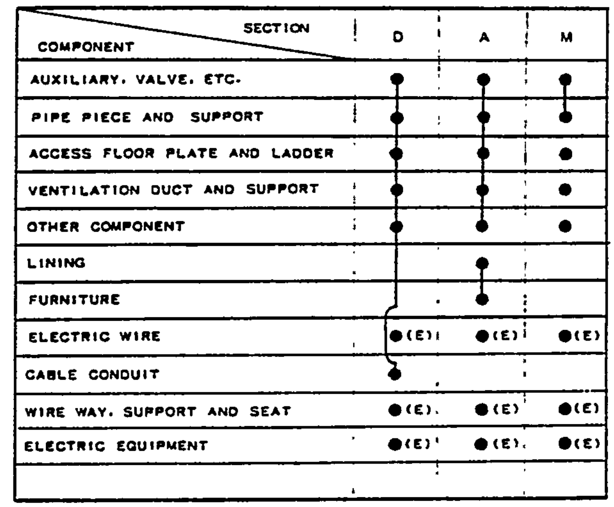


FIGURE 4-10: Ideal separation for fitting types for composite arrangements.. Each of the DAME design groups has, its collsboration with production engineers in the corresponding shop, optimised the grouping of fitting types per composite arrangement. As noted the electrical group (E) separates by DAM as well ss by fitting types. As shown in accordanced with group technology, i.e., separation by problems, electric-cable conduit pieces are on the composite prepared by the deck design group (D) just as if they were pipe pieces.

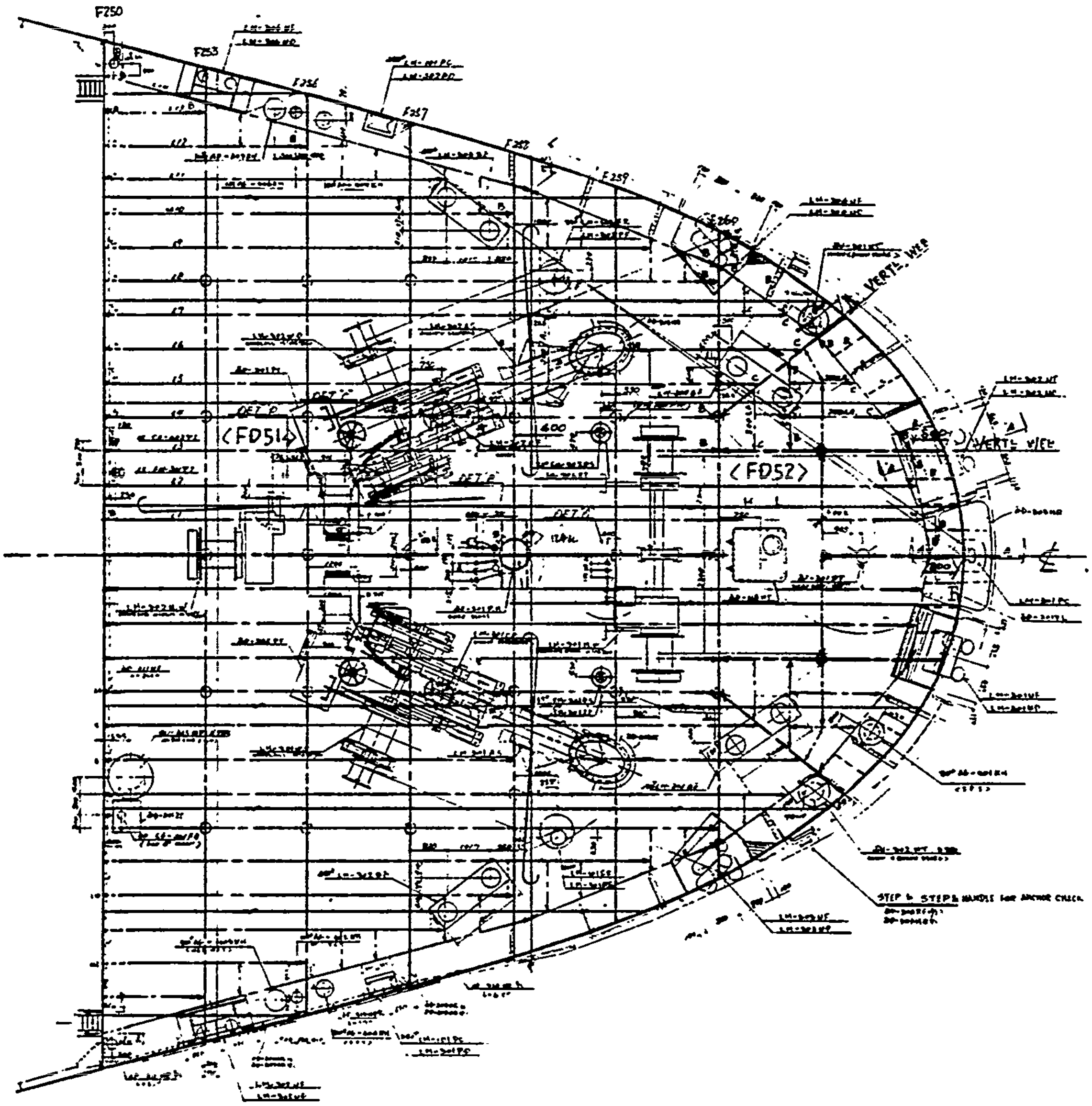
4.3 *Work Instruction Design*

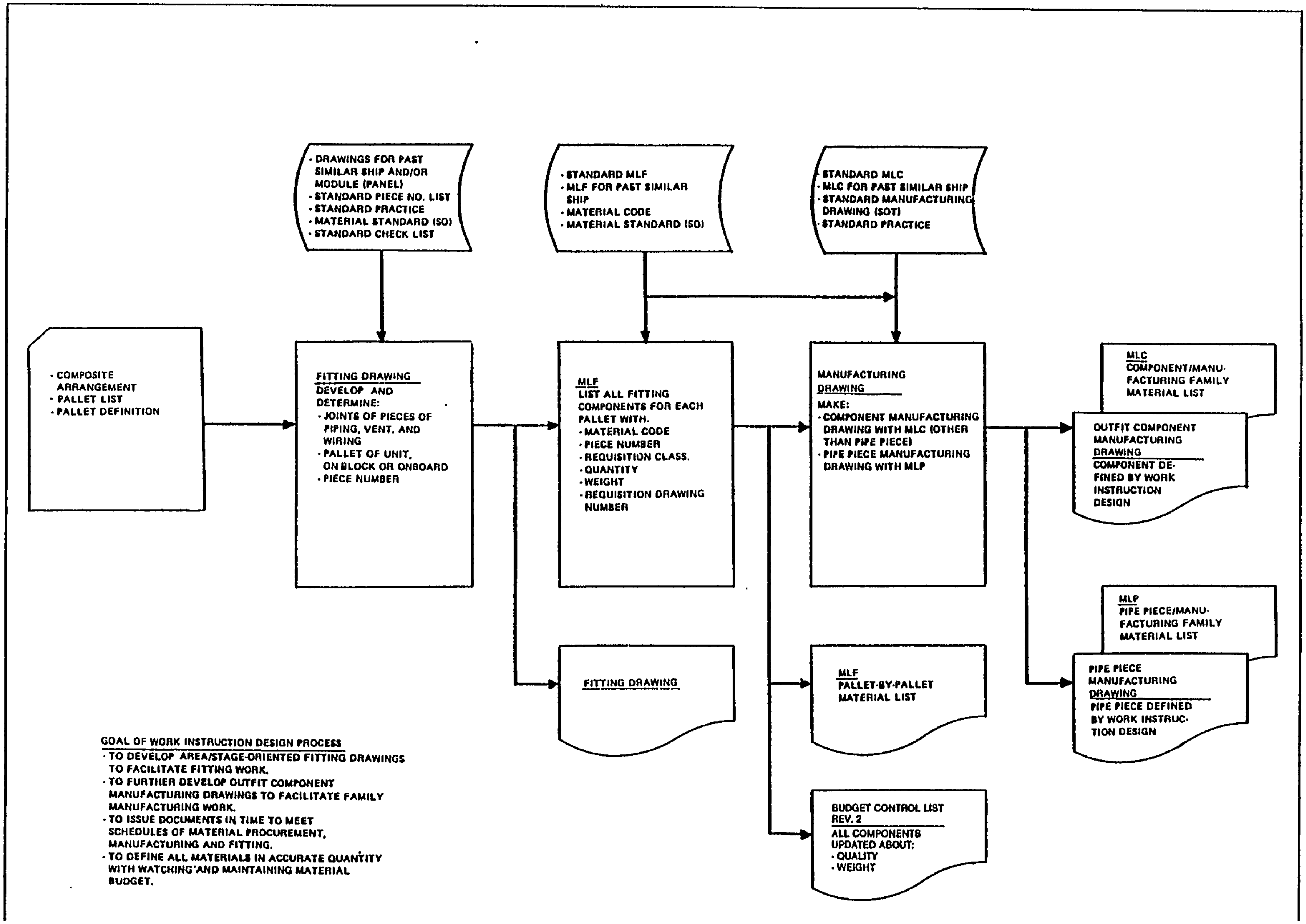
Within functional requirements and component positions defined by the preceding design processes, work instruction design finalizes details and material requirements on stage plans, i.e., drawings on which zone/area/stage classifications are indicated. These are most pertinent for production as they provide manufacturing (fabrication) and fitting (assembly) instructions which match the way work is organized. Pigure 4-12 displays the flow of work-instruction design processes. Figure 4-13 illustrates the transformation of information by system, including material lists, to that grouped by zone/area/stage. The same figure contains examples of simultaneous and final refinement of design details.

4.3.1 *Fitting Work Insrtuctions Drawings*

Preparation of fitting work instructions involves:

- piece-by-piece definition of all fittings not previously defined, e.g., exact definition of pipe pieces and pipe supports,
- final definition of each pallet by the product aspects which characterize the production processes, i.e., problem *area* and *stage,* and
- producing material lists for fitting (MLF) per pallet.


F250
F253
F256
F257
F259
<FD51>
<FD52>
VERT'L WEB
VERT'L VIEW
600
STEP & STEPS HANDLE FOR ANCHOR CHECK



· DRAWINGS FOR PAST SIMILAR SHIP AND/OR MODULE (PANEL)
· STANDARD PIECE NO. LIST
· STANDARD PRACTICE
· MATERIAL STANDARD (SO)
· STANDARD CHECK LIST
· STANDARD MLF
· MLF FOR PAST SIMILAR SHIP
· MATERIAL CODE
· MATERIAL STANDARD (SO)
· STANDARD MLC
· MLC FOR PAST SIMILAR SHIP
· STANDARD MANUFACTURING DRAWING (SOT)
· STANDARD PRACTICE
· COMPOSITE ARRANGEMENT
· PALLET LIST
· PALLET DEFINITION
FITTING DRAWING
DEVELOP AND DETERMINE:
· JOINTS OF PIECES OF PIPING, VENT. AND WIRING
· PALLET OF UNIT, ON BLOCK OR ONBOARD
· PIECE NUMBER
MLF
LIST ALL FITTING COMPONENTS FOR EACH PALLET WITH.
· MATERIAL CODE
· PIECE NUMBER
· REQUISITION CLASS.
· QUANTITY
· WEIGHT
· REQUISITION DRAWING NUMBER
MANUFACTURING DRAWING
MAKE:
· COMPONENT MANUFACTURING DRAWING WITH MLC (OTHER THAN PIPE PIECE)
· PIPE PIECE MANUFACTURING DRAWING WITH MLP
MLC
COMPONENT/MANUFACTURING FAMILY MATERIAL LIST
OUTFIT COMPONENT MANUFACTURING DRAWING
COMPONENT DEFINED BY WORK INSTRUCTION DESIGN
MLP
PIPE PIECE/MANUFACTURING FAMILY MATERIAL LIST
PIPE PIECE MANUFACTURING DRAWING
PIPE PIECE DEFINED BY WORK INSTRUCTION DESIGN
FITTING DRAWING
MLF
PALLET-BY-PALLET MATERIAL LIST
BUDGET CONTROL LIST REV. 2
ALL COMPONENTS UPDATED ABOUT:
· QUALITY
· WEIGHT
GOAL OF WORK INSTRUCTION DESIGN PROCESS
· TO DEVELOP AREA/STAGE-ORIENTED FITTING DRAWINGS TO FACILITATE FITTING WORK.
· TO FURTHER DEVELOP OUTFIT COMPONENT MANUFACTURING DRAWINGS TO FACILITATE FAMILY MANUFACTURING WORK.
· TO ISSUE DOCUMENTS IN TIME TO MEET SCHEDULES OF MATERIAL PROCUREMENT, MANUFACTURING AND FITTING.
· TO DEFINE ALL MATERIALS IN ACCURATE QUANTITY WITH WATCHING AND MAINTAINING MATERIAL BUDGET.

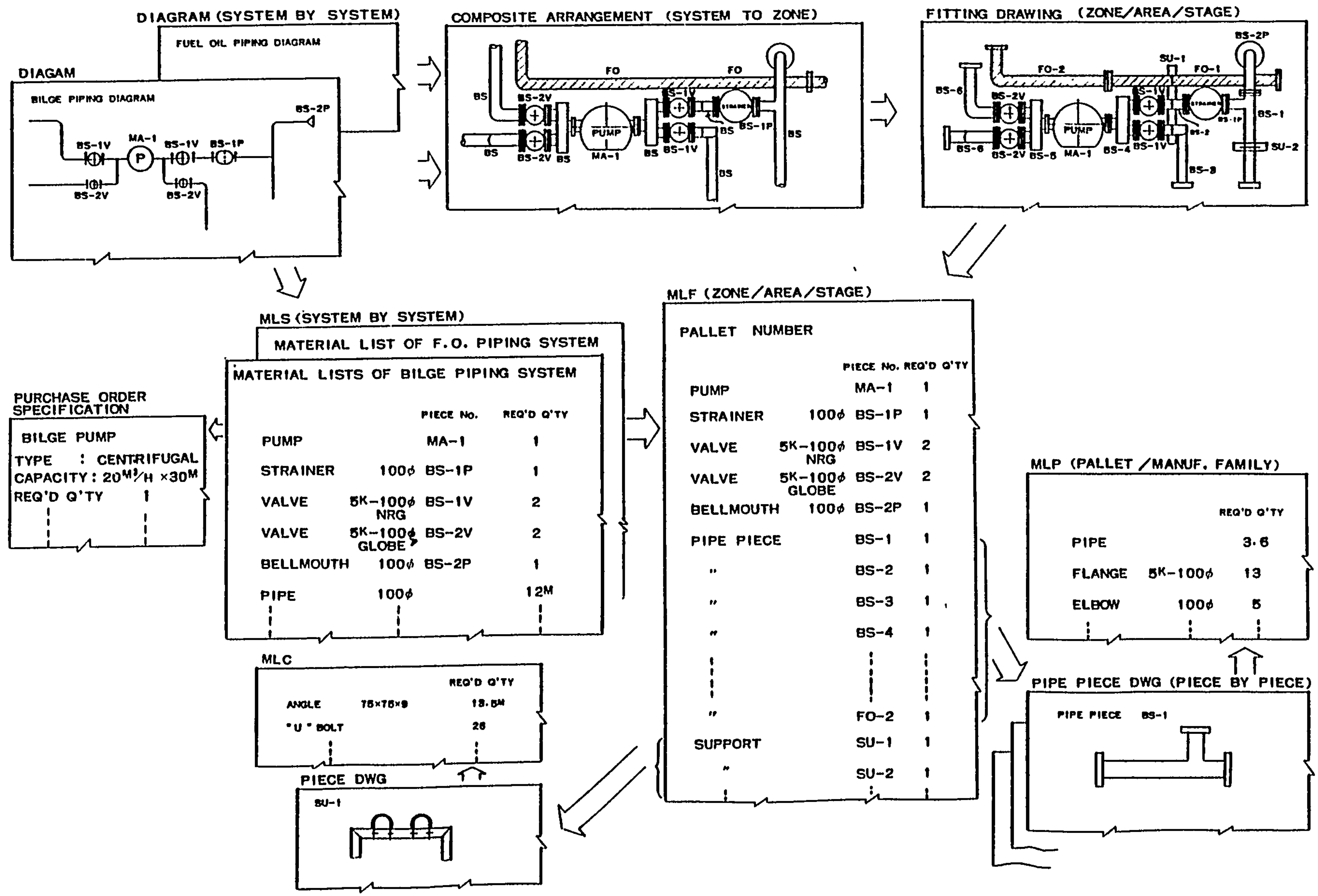


FIGURE 4-13: Flow of design and material definition development. The composite drafts which should appear between the diagrams and composite arrangements are omitted for simplicity.

Considering the outfitting stages and flows of outfit components to be issued, as illustrated in Figure 4-14, the composite arrangements are used to make decisions regarding:

- fitting stages for components, and
- joints in distributive systems needed to facilitate on-unit and on-block outfitting.

Then, using a light-line reproducible copy of the composite arrangement, the outlines of components selected to be fitted on-unit are made bolder. This process is repeated with other light-line reproducible copies of the same composite arrangement to separately designate components to be fitted on-block and on-board.

The marked composite arrangements are supplemented With:

- pallet numbers, i.e., code numbers which identify zone/area/stage for each pallet,
- all joints not previously defined in distributive systems,
- supports for distributive systems,
- piece numbers identifying each piece of and support for distributive systems, and
- dimensions of auxiliary machinery foundations.

Because of its derivation by stage from composite arrangements, each fitting work instruction drawing generally includes several pallets.

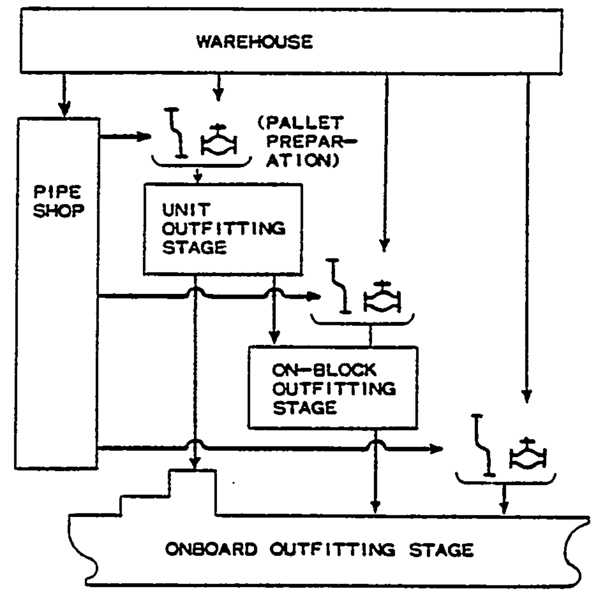


FIGURE 4-14: Outfitting stages and fitting flows showing coordinated palletizing by a pipe shop and warehouse. Designers must maintain awareness of the most productive flows, i.e., in their normal order of preference on-unit and on-block.

4.3.2 *Material Lists for Fitting (MLF)*

Upon completion of each fitting instruction drawing all outfit components required per pallet are listed on MLF. The rather extensive descriptions include:

- material code,
- piece number,
- material cost-classification number,
- material listing classification,
- material requisition classification,
- material control classification,
- material purchasing classification,
- parent/child sign,
- weight,
- quantity,
- MLF zone, and
- drawing number corresponding to procurement and fitting work.

With respect to a specific zone/area/stage each MLF is *used for:*

- collection (palletizing) of outfit components in anticipation of fitting work,
- recording weight of outfit components to be used for Calculating the pallet's fitting-work amount and contribution to ship's outfit weight, and
- updating the material identification status.

The data on MLF are compared by material controllers in the production control department to inventory and to the requisition status in order to insure that all material needs are anticipated. Obviously, very much is dependent on material definition. Further, the need to provide so much information for each fitting is a heavy burden, particularly on those who prepare MLF. Standardization of fittings and computerization to facilitate material sorting and collating by the various classifications is virtually indispensable. In shipyards where zone orientation is most progressed, the program for sorting and collating material consistent with the foregoing is regarded as the most important computer program in shipbuilding. Programs for computer-aided drawing, lofting, scheduling, payroll, etc., are not withstanding.

4.3.3 *Manufacturing Work Instruction Drawings*

Items listed on MLF which must be custom manufactured are described in manufacturing work instructions in sufficient detail to permit either in-house or outside manufacture. Major such items, e.g., masts, booms, unique tanks, etc., which require long lead-times for procurement of raw materials or for manufacture are identified during the functional design process and treated as exceptions.

Aside from the major items, each pallet generally contains various kinds of items, e.g., pipe pieces, ventilation duct pieces, ladders, access way pieces, handrail pieces and supports. Manufacturing drawings are prepared for each component per pallet per kind of item in accordance with the grouping of components in pallets on fitting drawings. Thus, all of the manufacturing drawings for components of one kind within a pallet are grouped so that they cart be assigned for manufacture per pallet regardless of where they are to be manufactured.

Components, other than pipe pieces, of one kind are almost always of the same manufacturing family and require the same lead times. Thus, all such components can be included in a single manufacturing drawing. Drawings by kind of item per pallet, facilitate issuing work orders and just-in-time manufacture of the required items.

Usually, the pipe pieces within a pallet represent different manufacturing families and have different lead times. Thus, pipe pieces per pallet are further grouped by pipe-piece family. This permits sorting, ideally by computer, so that the starts of manufacture of the pipe pieces requiring the long lead-times, are commensurately earlier in order to insure that all pipe pieces required for a pallet are available at the same time for fitting work.'

4.3.4 *Material Lists for Manufacturing (MLP & MLC)*

Upon completion of each manufacturing instruction drawing, all raw materials are listed on MLP and MLC for manufacture of pipe pieces and components other than pipes respectively. The rather extensive descriptions described in Part 4.3.2 are employed but are relatively easy to incorporate through standardization and computerization programs. Similarly, the data on MLP and MLC, both for parent and child, are again compared to MLS, inventory and the requisition status and are employed to refine outfit weights and the predicted *amounts* of fitting work. More especially, the data is employed to predict the amounts of manufacturing work rquired.

See the National Shipbuilding Research Program publication "pipe Piece Family Manufacturing - March 1982."

5.0 MATERIAL DEFINITION

How well designers define *all* materials is a singular element of competition in modem shipbuilding. Material control, procurement and warehousing and ultimately how well shops can organize work, are critically dependent upon how effectively designers define materials. The sufficiency and timeliness of designer prepared specifications and/or drawings necessary for procurement are especially critical.

Effective material definition is highly dependent on the discriminating use of time. During functional design emphasis is assigned to identifying LT materials from MIS and completing the documentation needed to initiate procurement. This includes bulk requirements for *child* materials, i.e., the components and raw materials which will eventually be listed on MLP and MLC as needed for in-house and outside manufacture of pipe pieces and components other than pipe. Final definition of ST materials is deferred until work instruction design when further refined material lists, MLF, MLP and MLC are produced.

5.1 Information Required

Figure 5-1 illustrates design, procurement and production relationships concerning material. As noted in the figure, and in Parts 4.1.2 and 4.3.2, rather extensive amounts of information are required. All outfit items are described in some kind of specifications coded with drawing (or purchase order) numbers which establish requirements. Then first, they are identified for the purposes of material procurement and production, budget and cost control, etc., with:

- material codes,
- piece numbers,
- pallet codes (or MLS material ordering zones), and
- material cost classification numbers.

Secondly, for the same purposes but specifically to identify the amount or volume of material needed, i.e., to create a budget control list, they are further defined by actual, or when necessary estimated:

- weights, and
- quantities (numbers of pieces, lengths, etc.)

Finally, for grouping to facilitate material procurement by designating the required material *procurement lanes, the* following are assigned:

- material listing Classification,
- material requisition classification,
- material control classification, and
- material purchasing classification.

Actually, assignment of the latter two classifications are material control functions. However, there is benefit if they are at least tentatively assigned by designers because they enable designers to better prioritize their contributions for on-time material procurement. Subsequently, such classifications are confirmed or revised by the material control group. Provided with pertinent feedback, designers are able to adjust accordingly.

Concurrently with executing material definition responsibtities, designers must strive to comply with the material allocations assigned by the budget control list and its subsequent revisions. In order to do this, designers are primarily concerned with material quantities as unit prices are the responsibility of people assigned for purchasing. However, when the shipbuilding specifications permit selection from many material grades, such as for joinery work, designers cannot be unmindfuI of costs. These combined responsibilities comprise a relatively heavy burden not encountered by traditional design groups. Standardization with required classifications assigned beforehand to each material code, is the most practical way to compensate.

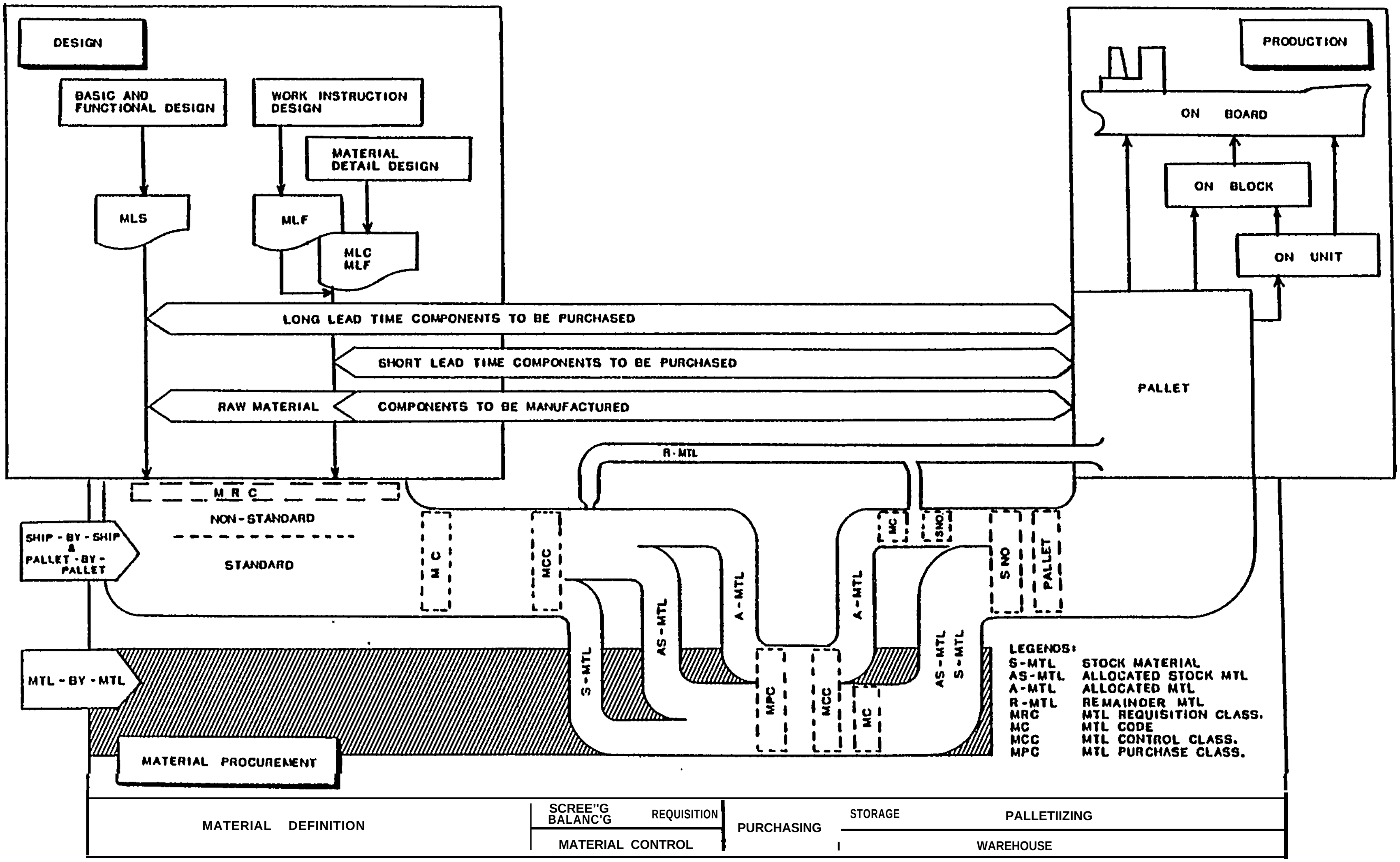


Figure 5-1: Relationships among design,material procurement and production activities. Timing for material lists and grouping of materials are shown.

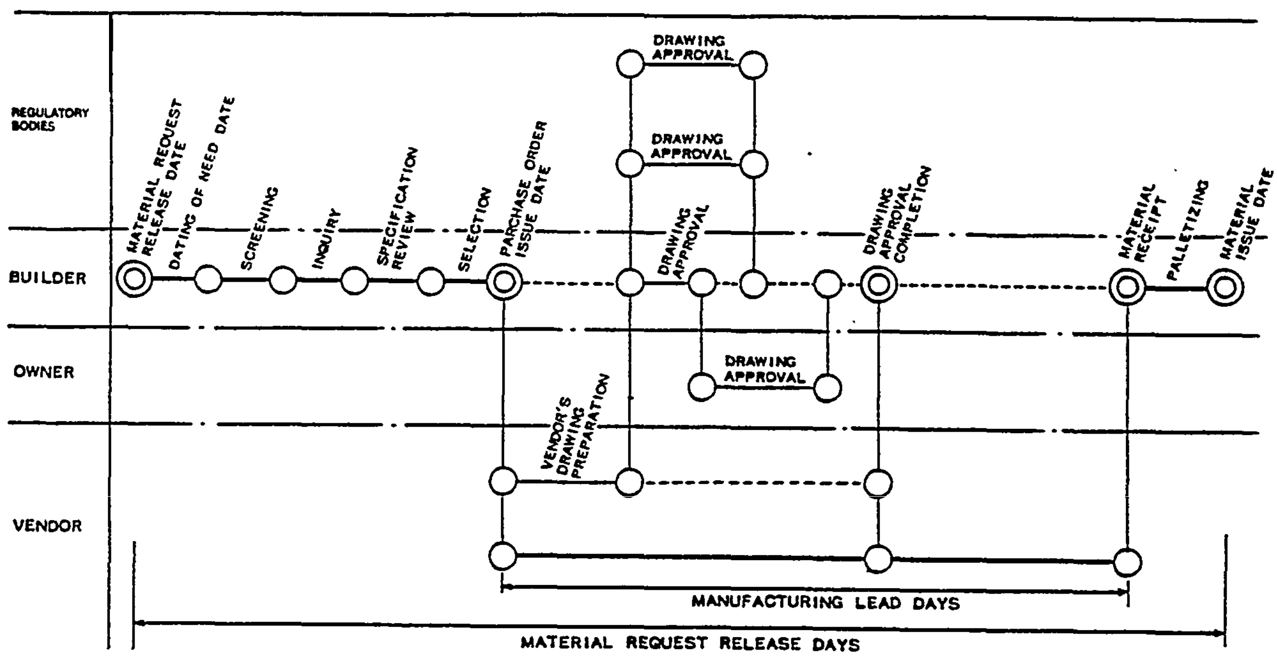


FIGURE 5-2: PERT presentation of a typical schedule for material procurement.

5.2 *Scheduling*

Outfit designers are required to supply sufficient and *timely* information necessary for procuring materials on time for manufacturing work in-house (and sometimes outside) and for assembly work on-unit, on-block and on-board. Design scheduling, as described in Part 3.3, must consider the lead times required between issue of material specifications and starts of work per pallet. Figure 5-2 displays a typical critical-path model showing the principal elements involved in material lead time.

Time is allocated for drawing approvals by the shipyard, owner, classification society and other regulatory bodies. Although all rquiremtmts for approvaJ are not shown on the critical path, frquently they have an effect. Thus, design scheduling, especially for functional design, must be done with particular regard for specific approvals required.

Design managers should be applying their best efforts for shortening times required for approvaIs. There are some other means, but, emphatically, standardization and modularization (see Footnote 1 of Chapter 3) are the best of all alternatives.

6.0 DESIGN CHANGES

Because even seemingly conventional merchant ships are relatively complex, outfit designers frequently encounter design changes. These may be due to revised requirements or to approval comments by an owner, classification society, or other regulatory body or due to a revised building strategy or insufficient design department study and development work. The numbers of such changes can be reduced and the impact of the remainder can be minimized by specifically organized preparations and countermeasures.

6.1 *Sources*

Some causes of design changes are suggested by the following:

- owner
  - different thinking and preferences
  - different practices
  - specialty
- classification society and other regulatory bodies
  - application of new rules and regulations
  - application of recommendations
  - different interpretations of rules and regulations
- production department
  - revised fitting stages
  - revised pipe joint locations, etc.
  - revised fitting positions of outfit components
- other groups of the design department
  - revised penetration locations for piping, ducting, etc.
  - revised machinery locations
  - resolution of a design reservation
  - revision of hull structure, e.g., hole, reinforcement, carling, etc.

A number of the changes caused by ***other groups of the design department, are the*** inevitable result of a calculated risk to allow each of the DAME groups to simultaneously progress functional, transition and work instruction design. Thus certain aspects of the design progress conditionally pending premeditated interface meetings.

For a typical merchant ship, the sources of changes are roughly in accordance with the following:

- 50% by owner,
- 25% by other design groups, and
- 25% by others.

6.2 *Preventitives*

Usually traditionalists are resigned to the impact of changes from ***outside sources*** and in some instances find such changes convenient to divert attention from changes caused by inadequate design study, coordination and development. However, a certain amount of debugging of the outside factors can be done beforehand.

Figure 6-1 illustrates the thought processes applied to avoid and minimize the effects due to changes. As shown, upon receipt of an inquiry there is research of an owner's preferences as manifested in the newest ships in the owner's fleet. This at least entails visits to such ships and if possible, discussions with the shipbuilders having experience with a particular owner. Special attention is given to details. For example, in one such investigation an owner's preference for unusually small tile in all wet spaces, significantly more expensive, was discovered before contract award. However, well developed standardization and modularization, formally included in the shipyard's practices and incorporated in proposed contract documents, remains the greatest assurance for both shipbuilder and owner to avoid change hassles which are generally costly to both.

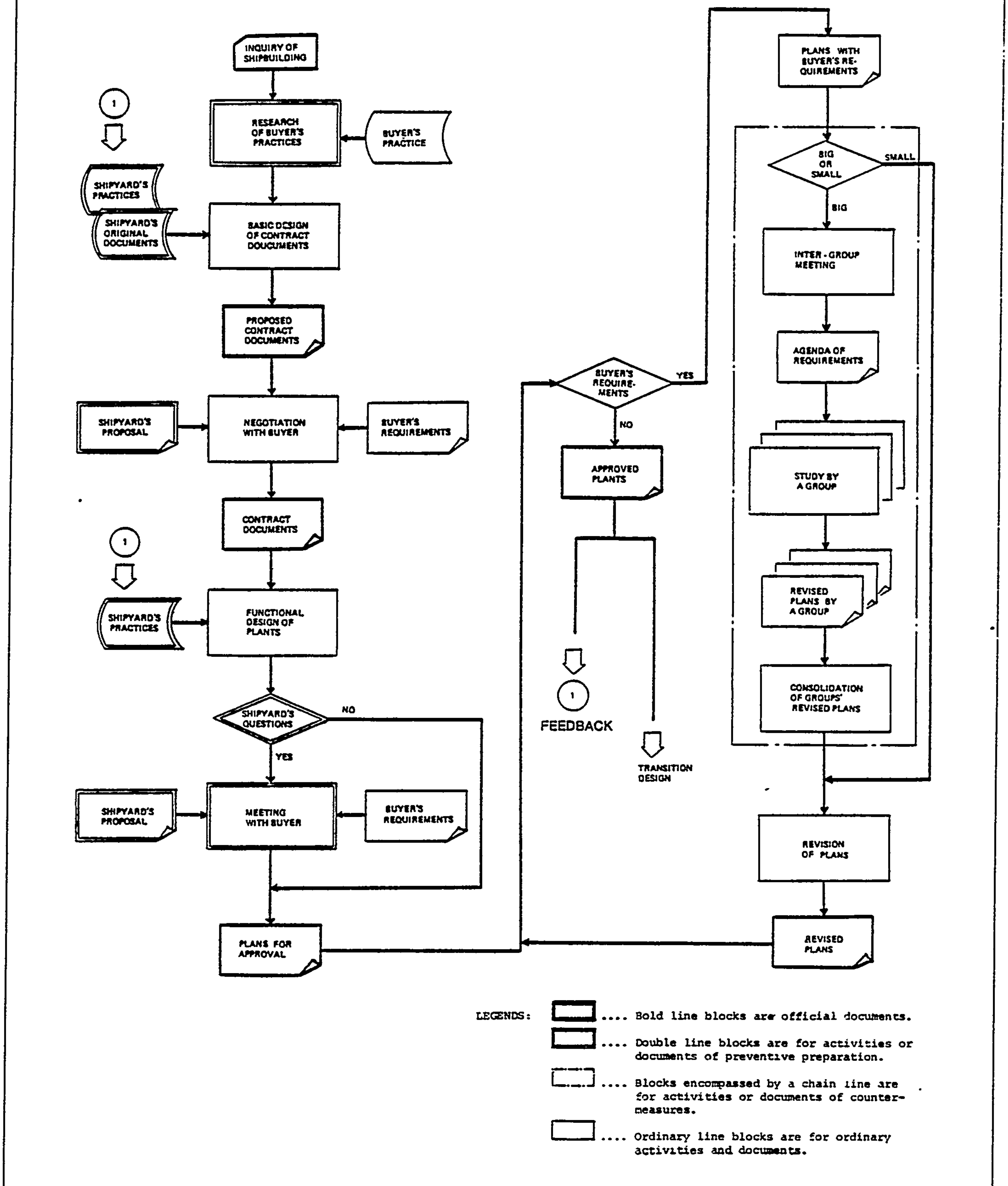


FIGURE 6-1: Preventiveness and countermeasure flow for design changes.

As changes caused by an owner are approximately half of the total encountered, shipyard design specialists participate during negotiations with an owner in order to discuss, solve and clarify the owner's requirements to be included in contract documents such as:

- contract specifications,
- general arrangement,
- midship section,
- machinery arrangement,
- cabin plan,
- piping practices,
- standard materials,
- standard for statistical control such as for accuracy, and
- standard surface preparation such as for painting.

If possible, the incorporation of key plans as additional contract documents will do much to avoid change encounters between an owner and shipbuilder and even between the diverse groups within a shipyard.

Another technique which minimizes change problems, is to formally meet with the owner about midway through the functional design process, to offer options the shipyard has with the contract that should be discussed in the context of the owner's requirements. The decisions so made, are then incorporated in key plans before their submittal for the owner's approval.

6.3 *Countermeasures*

As further noted in Figure 6-1, unavoidable changes which are large in scope, because they often have impact on more than one DAME group, are assimilated during a process which starts with an intergroup meeting. The engineer-in-charge of the group on which a change will have greatest impact, is assigned lead responsibfities for coordination and consolidation of other groups required studies and revisions.

At an intergroup meeting, the lead engineer-in-charge will:

- explain the reasons for and the basic substance of the change,
- acquire an understanding of other groups' pertinent design progress,
- squire greater knowledge of the effects of the change, and
- sometimes request that other groups stop design work wherever there is to be impact.

The study phase conducted by each concerned group typically includes:

- preparation of sketches,
- examination of technical possibilities,
- preparation of a cost estimate,
- ascertaining impact on the design schedule, and
- presentation of findings to the engineer-in-charge of the group having lead responsibility.

The consolidation phase includes:

- review of the concerned groups' inputs,
- decision to proceed, if possible, without other than shipyard approval,
- decision and submittal with cost adjustment as appropriate for buyer and/or Classification society approvals, and
- informing the concerned groups when to initiate revisions of plans.

Changes which are small in scope may require some or none of the foregoing dependent on their natures.

7.0 LOGIC AND PRINCIPLES

7.1 *Zone Orientation*

The most important principle in zone-oriented design is that material which is first assigned by function (system) is reassigned geographically. The reassignment is made for the convenience of workers by specifically deining the material required to do an amount of work in a specific zone during a designated stage. When the work so defined is classified by a problem category, all aspects exist for defting a *pallet* by zone/area/stage. This entails grouping information per pallet on a set of documents as follows:

- fitting instruction, a composite arrangement indicating the locations of fittings,
- material list for fitting (MLF) identifying the fittings necessary to perform the work specified by the pallet, and
- manufacturing instructions and their material lists (MLP and MLC), which are necessary to custom manufacture certain fittings that are listed in the MLF, e.g., pipe pieces, ladders, and drain-collecting tanks.

On such documents, material is attributed only to *location.* Manufacturing and fitting workers are not encumbered with material assigned by *function.* For example, a stop valve for a fuel-oil transfer pump is coded as a component for a specific zone/area/stage by a piece number and pallet number. Designating the valve as one of the valves in the fuel-oil piping system is extraneous and requires more understanding than is necessary for manufacturing and fitting work, Thus, piece and pallet numbers are used for identifying materials on work instructions, on material lists, during palletizing and during outfit work on-unit, on-block and on-board.

Following such fitting work, there is often need for function identification such as for marking and testing work. Thus, the employment of piece numbers which are coded to identify functional as well as geographical attributes, is prudent.

Material assigned geographically, frees manufacturing and fitting workers from the need to comprehend relatively complex knowledge of the purposes of fittings. They need only to understand the association of piece numbers with fittings illustrated on a drawing, to match the numbers to those on fittings in a provided material kit (pallett) and to install the fittings exactly as shown on the drawing. Well planned piece numbers can *sometimes* convey a required or recommended fitting squence: see Figure 7-1. With such planning performed for them, workers are then able to concentrate on understanding the work processes so that they may better participate in efforts to constantly improve productivity and quality.

7.2 *Design Development by Zones*

The same principle which governs grouping material by zone, leads to development of the portions of all systems in a zone at the same time. In contrast, conventional design progresses system by system regardless of zone-by-zone hull construction which is universal for constructing welded hulls. Thus, any outfit strategy which is not zone-oriented, inherently Conflicts. Due to different priorities, valuable time at the beginning of a system-by-system detail-design effort is spent developing portions of systems that will not be needed for some time.

Scheduling design development work must be in accordance with the principle to group information by zone. For example, pipe runs in the same zone, regardless of their system affiliations, are developed at the same time and are arranged parallel to each other wherever possible. This is an essential means for shifting much fitting work from inefficient piece-by-piece outfitting on-board to outfitting on-unit in a shop where safety, quality and productivity are considerably enhanced. Thus, planning pipe routes and pipe-piece types and locations of pipe supports on fitting instmctions are very important functions. Such concerns must be reflected in contract drawings, such as general and machinery arrangements, after careful and comprehensive planning.

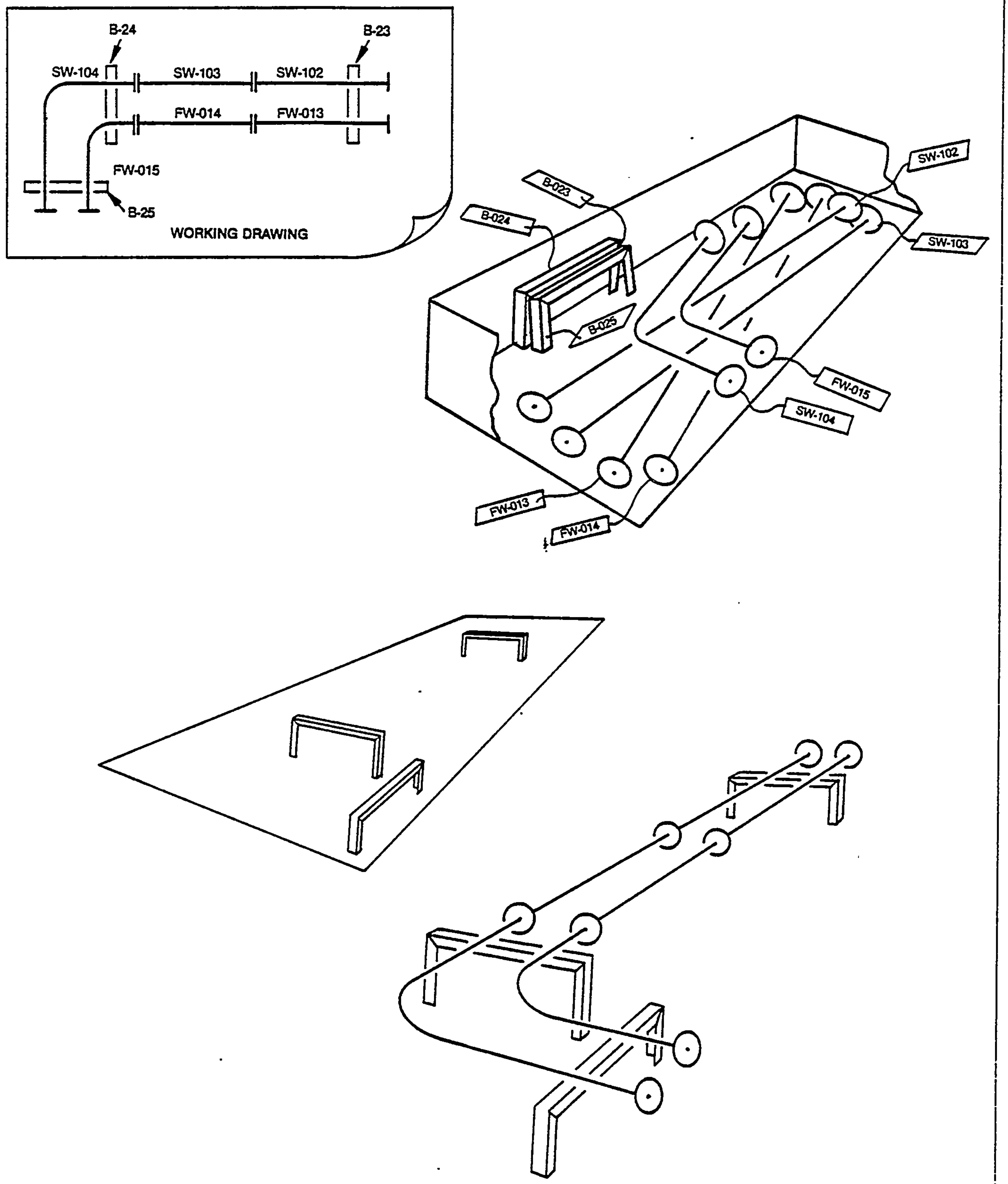


FIGURE 7-1: Material assigned geographically as shown, greatly simplifies fitting work instructions.

Approaches for achieving such zone orientation include:

- showing *pipe passages* reserved for multiple pipe runs on contract arrangements, particularly in conjested zones such as around a main engine or ship's service generator, or as in double bottoms, living quarters, etc.; see Figures 7-2 and 7-3,
- aligning pipe runs parallel to the ship's X, Y and Z axes, as shown in Figure 7-4, to achieve consolidation of pipe pieces for efficient assembly on-unit instead of "tangled spaghetti" pipe runs that must be assembled piece by piece on-board.
- detailing common support for multiple pipe runs on work instructions; see Figure 7-5, and
- aligning pipes on their outside diameters instead of their centerlines, as shown in Figure 7-6, in order to simplify supports.

7.3 Product Orientation

In modem shipbuilding such things as pipe pieces and outfit units are regarded as interim goals or *interim products. The* most advanced shipbuilders are product oriented, i.e., they have expertise for contriving interim products that can be manufactured or assembled on real or virtual production lines in accordance with the principles of group technology.

All machinery, equipment and pipes are arranged to ensure minimum production costs with special emphasis on man-hours rquired. This objective is mostly achieved by applying the principle that performing outfit work at the earliest stage, on-unit, is smarter costs less, whereas performing outfit work on-board is *harder and* most expensive. The following are some outfit measures applied in order to both reduce costs and make work easier:

- machinery and equipment which are functionally affiliated are, when practicable, arranged close together, as shown in Figure 7-7, to facilitate packaging in units (Note: In some instances where a traditional design was revised for zone orientation, the combining of foundations and supports resulted in weight reductions of as much as 30%.),
- common foundations are used for such machinery and immediately adjacent walkways and piping share common supports,
- as far as practicable, pipe bends are restricted to 90 and 45 degrees as means for achieving accuracy in joints between pipe pieces, units, and between pipes and machinery (Note: In pipe shops which employ statistical control methods for constantly improving productivity and quality, data collection and analysis are greatly reduced when pipe bends are so limited.),
- even pipes which simply pass through a zone for a contemplated outfit unit are designated as part of the unit for outfitting on-unit as shown in Figure 7-8,
- as far as practicable small tanks and foundations for machinery, equipment, etc., are designed so as to be independent of hull structure, see Figure 7-9,
- pipe pieces which are to be installed on-board, are limited in both length and weight so as to be easy for one worker to handle, and
- pipe pieces per pipe piece family per ship are recorded so that managers can constantly strive to reduce the total number of pipe pieces and the percentages of the more expensive pipe piece types.

7.4 Hull Structural Design to Facilitate Outfitting

The most effective shipbuilders practice integrated hull construction, outfitting and painting (IHOP).' No one type of work proceeds without evaluating its cost impact on another. Sometimes additional structural weight or hull construction man-hours can result in outfit savings which more than offset the added costs. Where IHOP is practiced, many hull features and block bounties are determined in consideration of outfit convenience. For example:

- Block joints for engine-room double-bottom blocks are located above the grating level so that fitting can progress in this normally congested region to the fullest extent before hull erection. That is, space does not have to be reserved adjacent to block joints for access during erection welding. See Figure 7-10.
- As much as practicable, blocks, particularly for engine-room flats, are defined to be stable when upside down and when right-side up as shown in Figure 7-11. This facilitates down hand outfitting on ceilings and decks.
- In order to facilitate fitting pipe penetrations on-block, *shelf plates (portions* of bulkheads or decks) are provided as shown in Figure 7-12.
- The depths of beams are designed shorter to facilitate fitting pipe runs as illustrated in Figure 7-9. The man-hours saved more than compensate for the thicker beam plates required as compared to those for beams designed only from a strength viewpoint.
- Trunks are provided in deckhouses for vertical pipe and electric-cable runs, even at the expense of increased weight, as shown in Figure 7-3.

More knowledge of hull structural design to facilitate outfitting is contained in the National Shipbuilding Research Program publication "Integrated Hull Construction, Outfitting and Painting (IHOP) - May 1983."

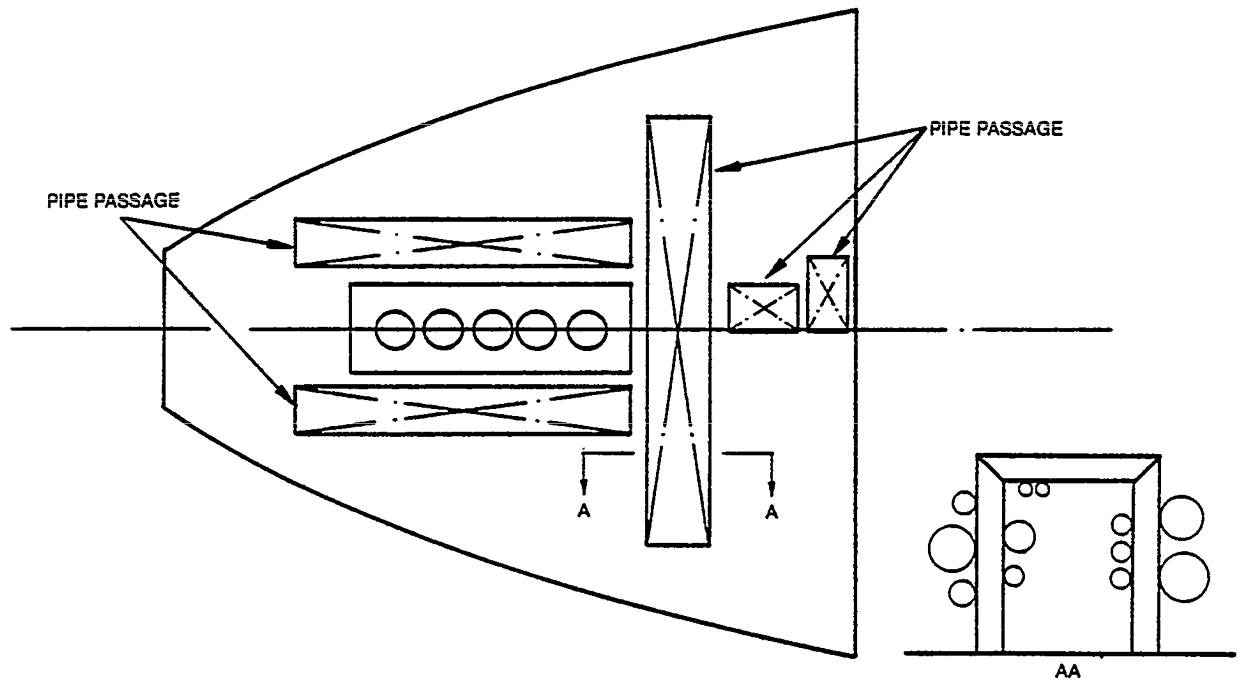


FIGURE 7-2: A tank-top plan for a machinery space showing the pipe passages reserved for multiple pipe runs. Sometimes the pipe passages that are planned to be beneath walkways, as shown, are supplemented by passages on ceilings.

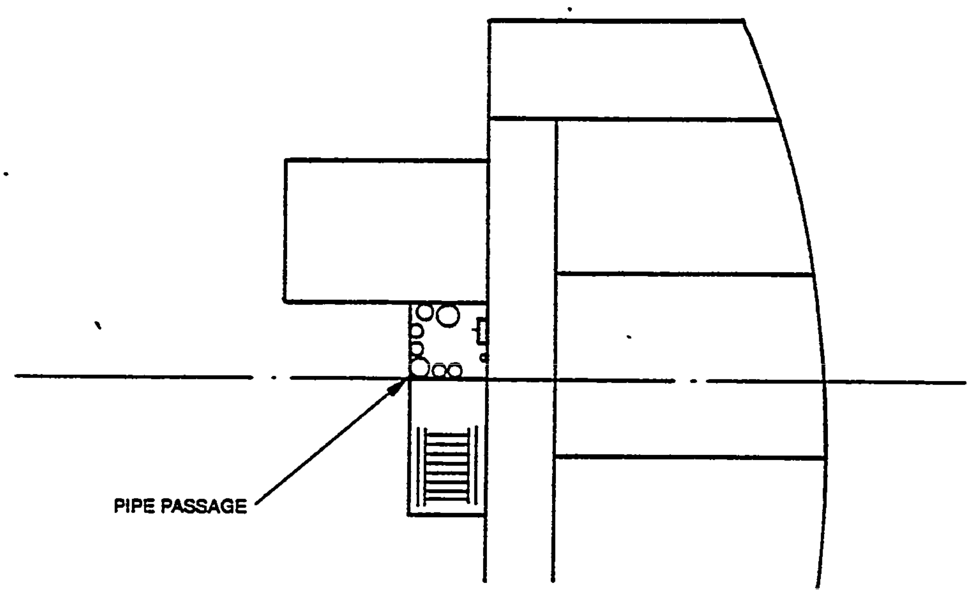


FIGURE 7-3: Pipe passages are planned against the sides of a vertical trunk which is included in the accomodation house arrangement specifically to enhance productivity.

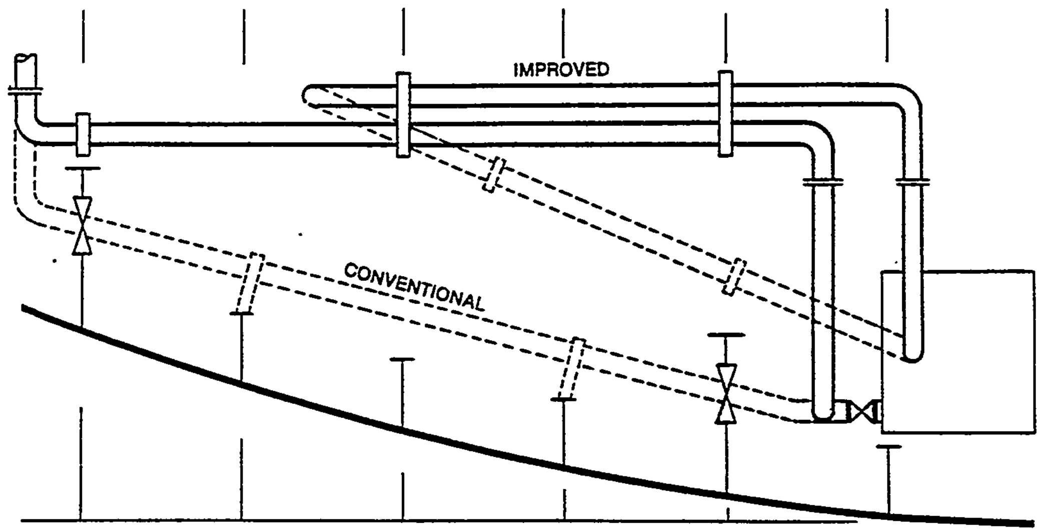


FIGURE 7-4: Aligning pipe runs parallel to a ship's XYZ-axes simplifies assembly work. More pipe pieces can be fitted on-unit instead of less efficient fitting on-block or on-board.

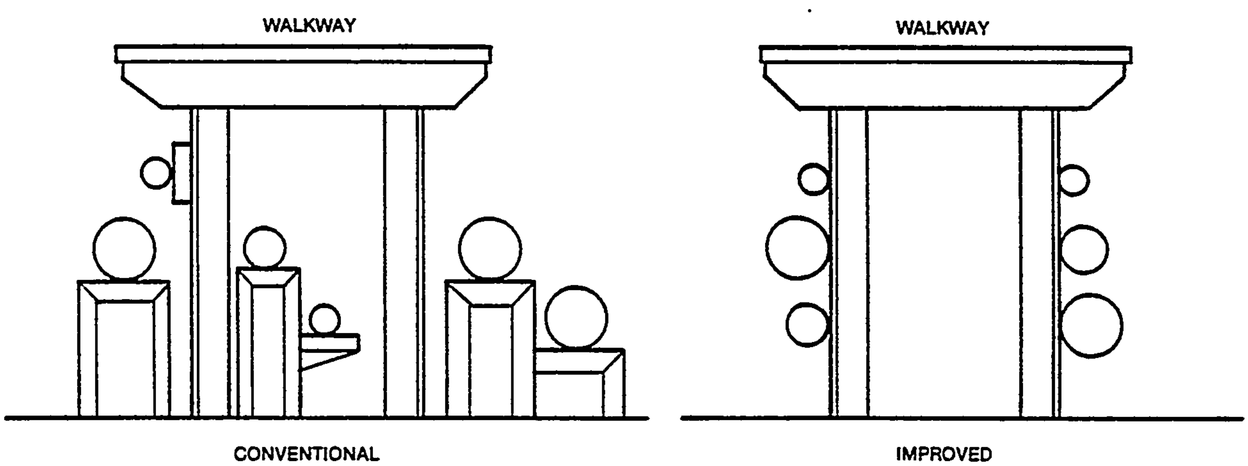


FIGURE 7-5: Zone orientation facilitates the use of common supports for various pipe systems. Manufacturing and fitting man-hours and weight are reduced. Such economies are virtually impossible to achieve when designers and shop people are assigned work system by system.

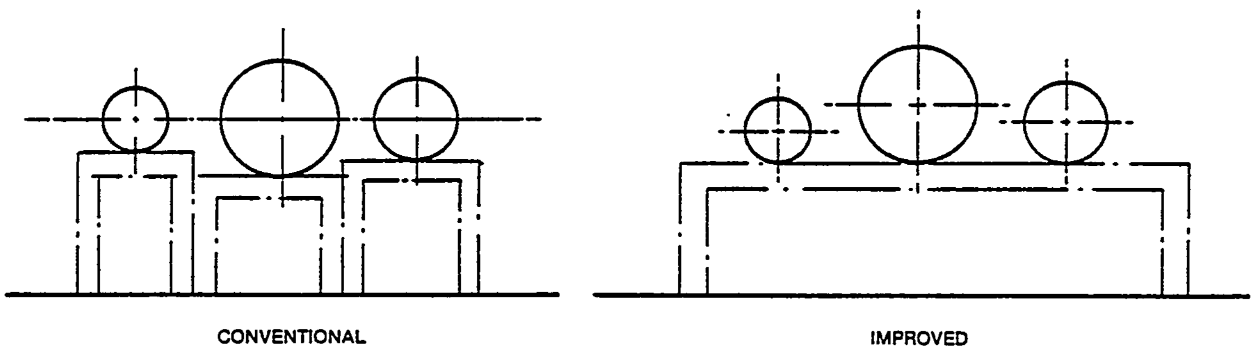


FIGURE 7-6: Even when attempting to develop zone-oriented methods some designers persist in locating parallel pipe runs so that their centerlines are in the same plane. Locating such runs so that their bottom surfaces are in the same plane is far more productive.

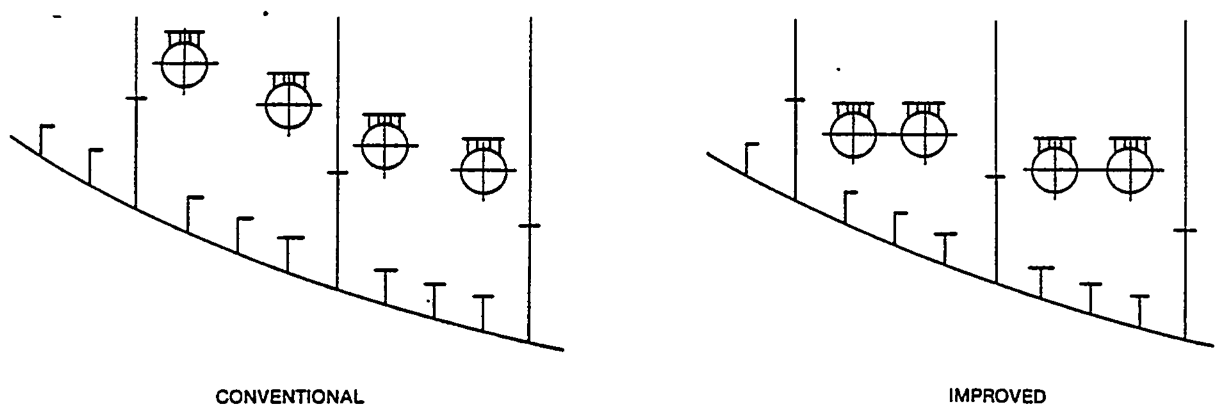


FIGURE 7-7: Product orientation is facilitated by grouping pumps side-by-side as shown.

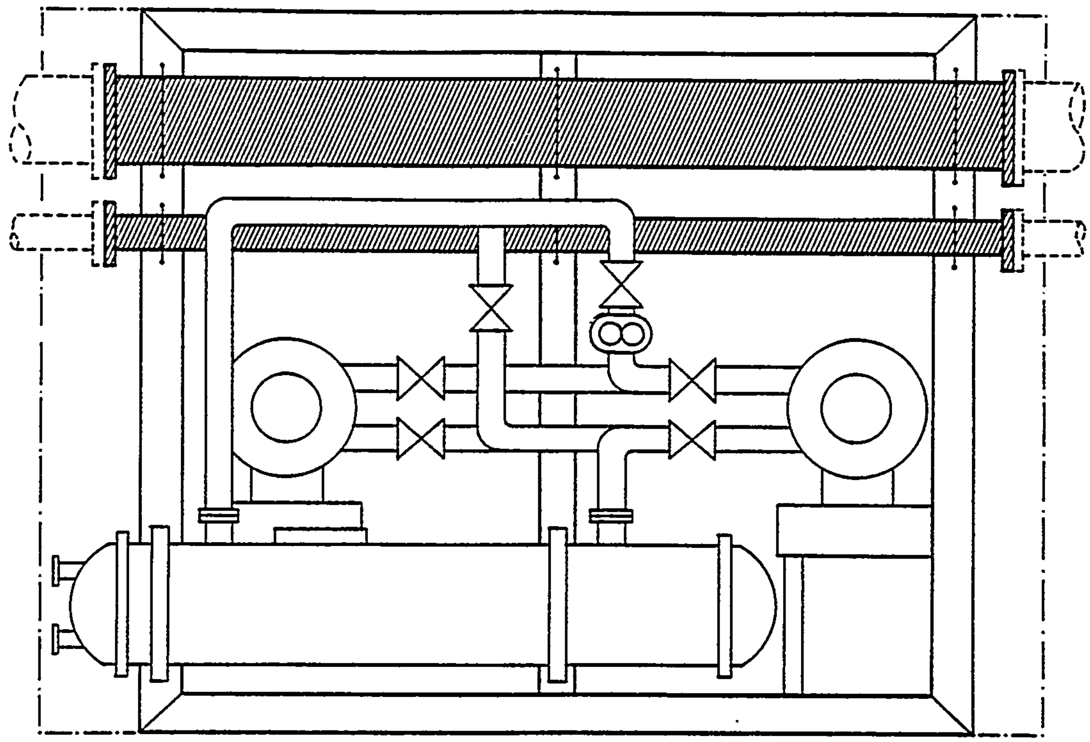


FIGURE 7-8: Even pipe pieces for other systems (shaded) which pass through a zone for a contemplated outfit unit, are included as part of the outfit unit.

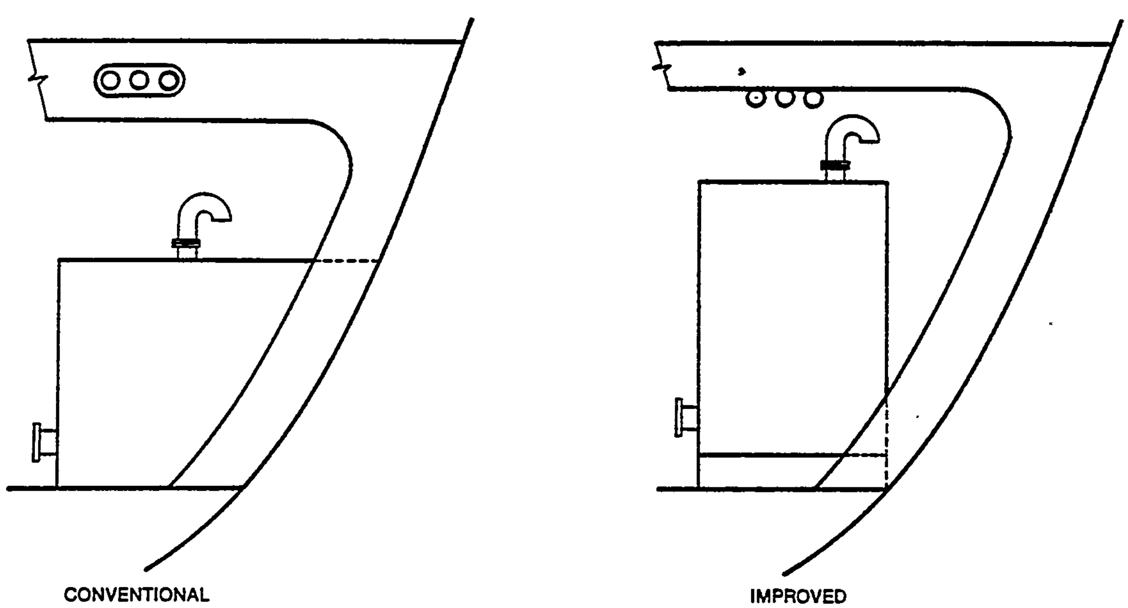


FIGURE 7-9: Since shop assembly of small tanks and foundations is more effective and since they can be readily fitted on block, they should be designed to be independent of the hull structure insofar as practicable.

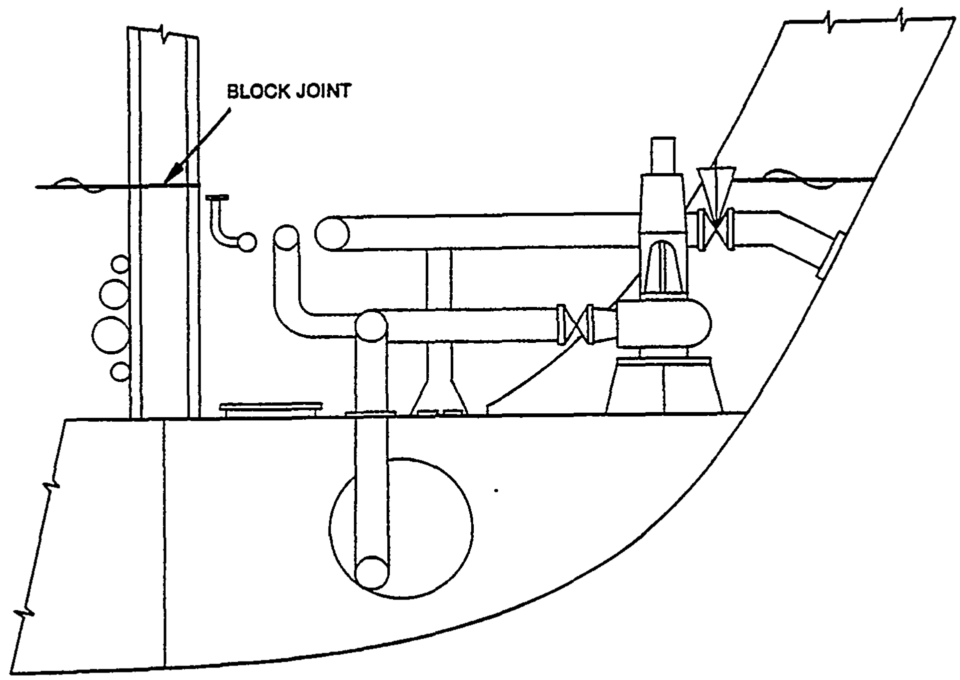


FIGURE 7-10: Hull construction and outfit production engineers collaborate so that blocks are defined to facilitate outfitting. As shown, block joints are located well above a congested arrangement on a tank top. The presence of machinery and piping, previously fitted on-block, does not interfere with erection welding.

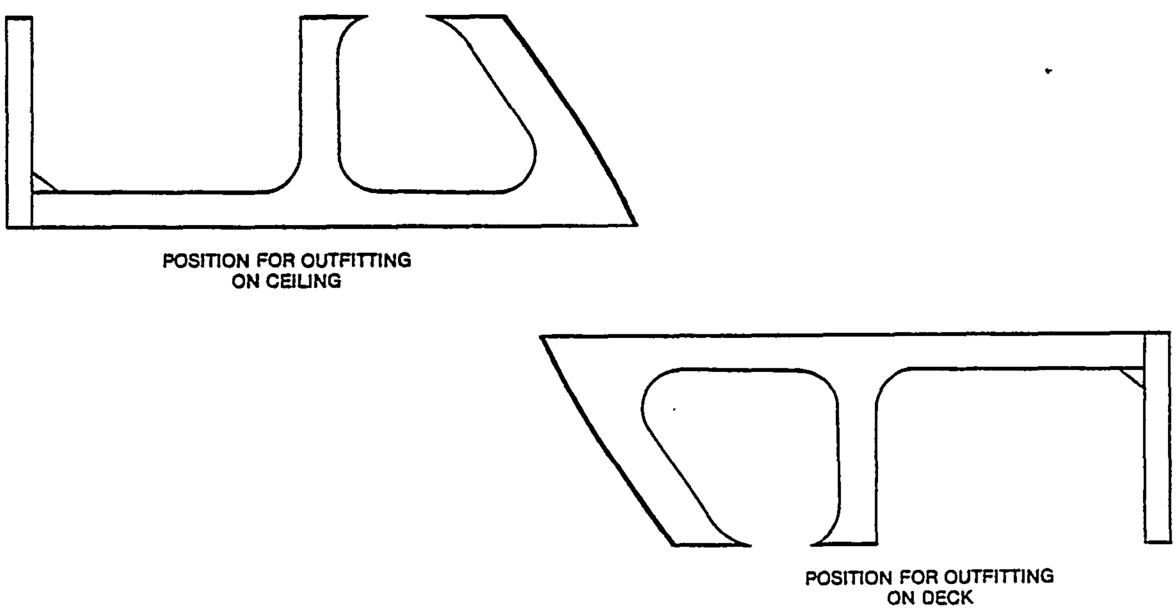


FIGURE 7-11: Working together, hull construction and outfit production engineers define blocks which are stable both when upside down for outfitting on ceilings and for outfitting on decks following turnover.

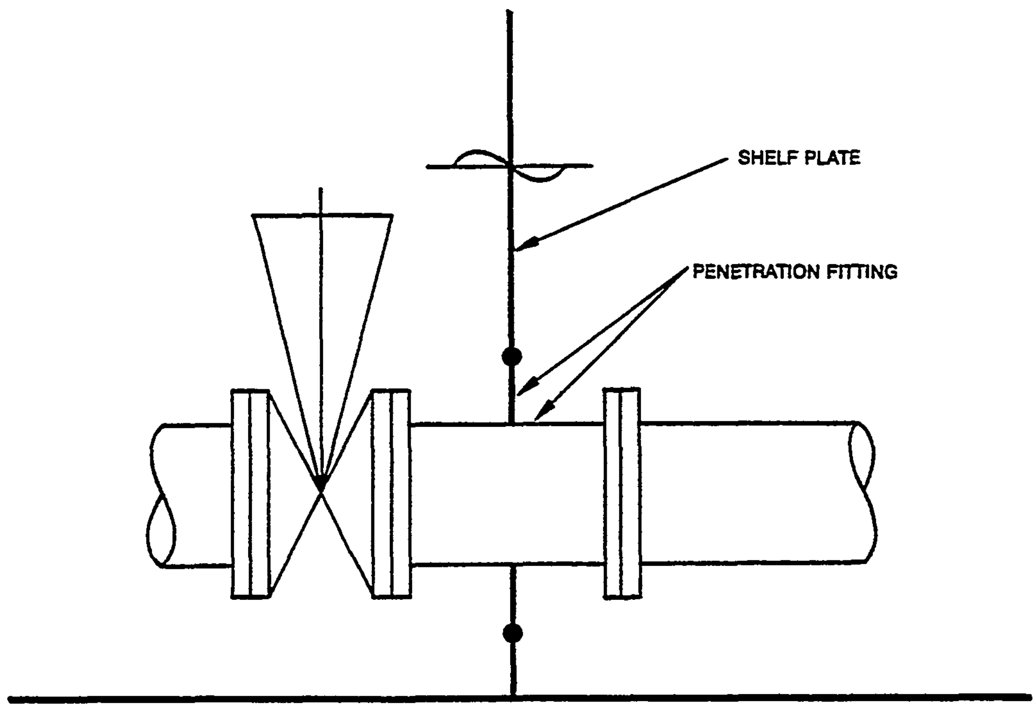


FIGURE 7-12: As shown, a portion of the bulkhead (shelf plate) is provided so that a pipe-penetration fitting can be fitted on-block.

7.5 Design Loop Developing

Theoretically, for design and production matters each phase should be completed before the next phase commences. As a practical competitive measure, overlapping the various phases is essential. Successor phases necessarily start before prerequisites are completed. Loop development (LODE) is an approach for resolving the dilemma.

7.5.1 *Logic*

As shown in Figure 7-13, a preliminary effort for transition and work instruction design starts at C' employing incomplete information from the functional design process. At C, the key plans from functional design are complete enough to undertake the major part of transition and work nstruction design because the number and extent of omissions (reservations) are not great enough to prevent substantial progress. By C", the functional design omissions are filled in, adjustments are made to adjacent concerns as necessary and the final key plans are issued. At D', sufficient transition and work instruction design is completed and the LODE logic is repeated. During overlap, there is constant communication of requirements and interchange of information as represented in the figure by the two-head arrows.

Although some rework results from the calculated risk to overlap phases, the contribution of LODE to shortening the period between contract award and delivery provides overwhelming benefit.

7.5.2 *Examples*

LODE logic has wide ranging application.

- *outfitting and hull structural design*

  Certain hull-structural key plans are required for some outfit key plans and vice versa. Such cross relationships exist and there is need to progress both concurrently in order to minimize the duration of functional design. For example, preparation of a mooring-system plan, as shown in Figure 4-3, requires some idea of how transverse and longitudinal strength members will be arranged beneath the forecastle deck. At the same time, preparation of the hull construction plan (fore Part) requires some knowledge of the major holes (penetrations) and reinforcements in deck structure needed for the mooring system. Application of LODE logic is essential.

  Individuals charged with preparing the pertinent hull structural and outfit key plans meet for the purpose of reviewing drawings for a past similar ship and/or design module. Their objective is to preliminarily locate outfit components and structural members. Then, both plans are developed separately until enough progress has been made to justify a second coordination meeting. At that meeting, arrangements and dimensions are finalized.

- *delayed vendor drawings*

  For various reasons, including the sometimes extensive approval processes required, vendor drawings, such as for boilers and winches, are frequently delayed. LODE logic is appropriate. Subsequent design development continues. Preliminary composite arrangements and fitting drawings are produced using drawings of similar vendor equipment. For this purpose, classifying and fding previously employed vendor equipment are very important. Accumulation of such knowledge discIoses similarities and realization of some standardization.

- *material listing*

  LODE logic is inherent in the techniques for defining material in MLS and MLF as described in Parts 4.1.2 and 4.3.2 respectively. Listing *all* required materials on MLS during functional design, by actual counts or estimates is a technique for quickly initiating procurement. Later, as material definition is refined during work instruction design, the definite quantities per pallet obtained from MLF, are substituted for those previ ously obtained from MLS.

- *pallet meetings*

  LODE logic is also inherent in the conduct of pallet meetings as described in Part 4.2.1 Briefly, the first such meeting outlines rough pallets, the second defines *the* pallets and the third finalizes them.

7.6 Computer-aided Scheduling System

The design department master schedule, as shown in Figure 3-3, carI be computer operated. Input data are:

- calendar for the coming three or four years with distinction of workdays and holidays,
- milestones, such as design start, keel laying, launching and delivery, for apportioning man-power by an assigned S-curve,
- man power available per month,
- milestones, such as design start, ked laying, launching and delivery, for apportioning man-power by an assigned S-curve,
- schedule for each ship by milestone calendar dates,
- total man-hours budgeted per ship,
- spent man-hours for past months to substitute for past man-hours budgeted and for adjustment of budgeted man-hours for future months, and
- percentage or fixed man-hours for leveling the total man-hour expenditures of all ships per month.

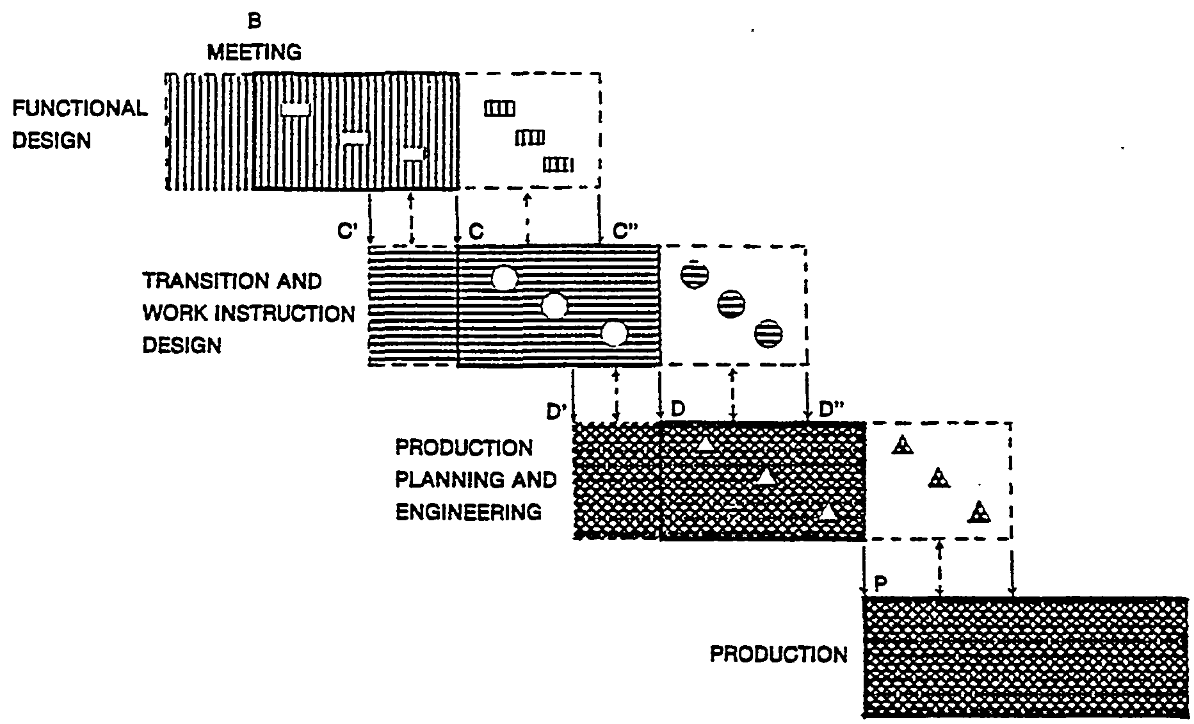


FIGURE 7-13: Logic Of Design *Loop* Developing (LODE).

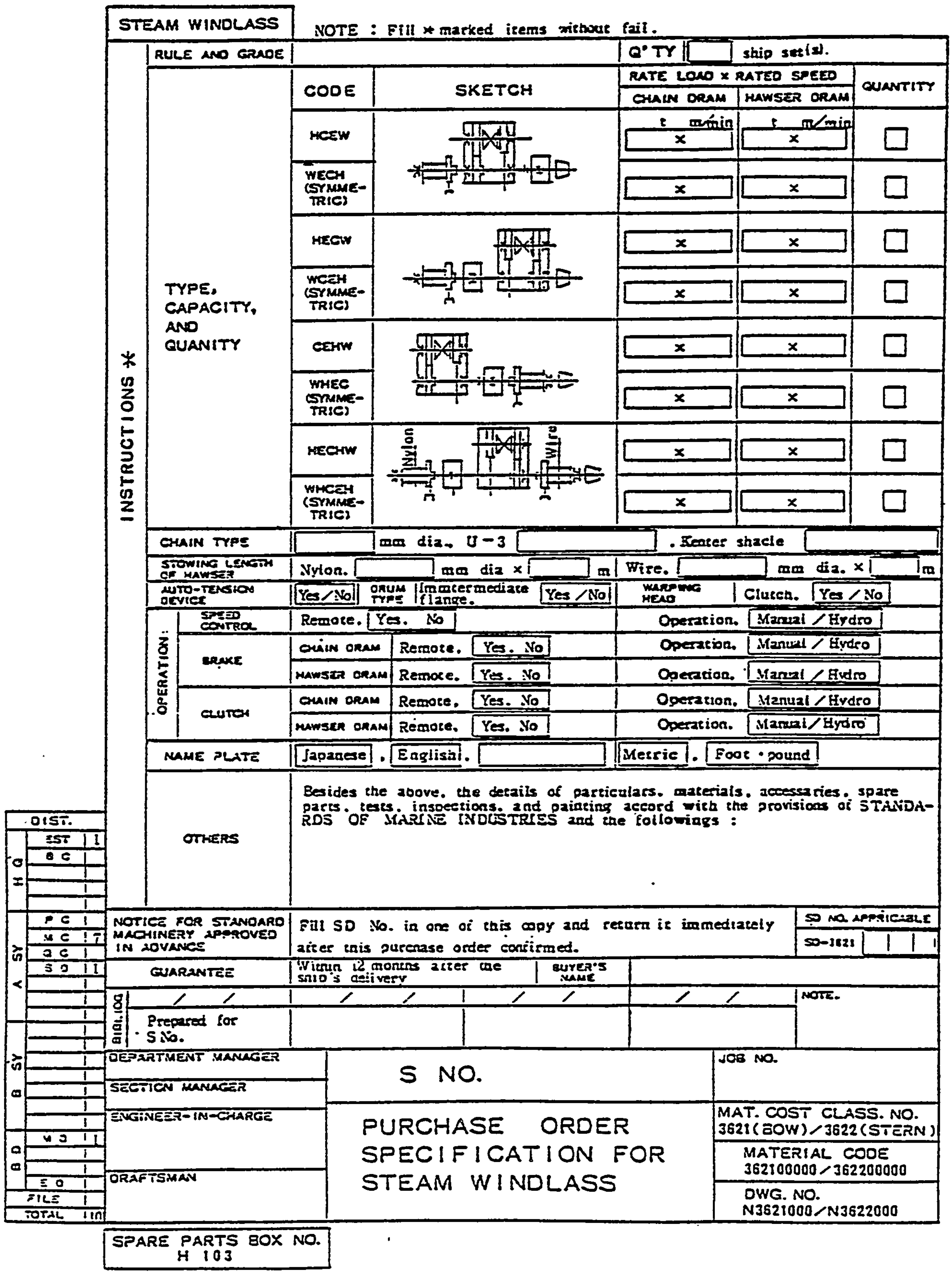
A computer system based on the foregoing, is widely applicable for planning and monitoring Other workload schedules. However, with any such system, computer-aided or manual, the usefulness of its output depends-very much on its input, The quality of the latter depends on how well design and production systems are standardized, modularized and organized for family and process lane production. Only through such measures can the collection and analysis of man-hour expenditures on past ships be sufficiently useful for predicting costs for future ships commensurate with competitive market circumstances.

7.7 *Format Standardization for Purchase Order Specifications*

Materials known by many names, e.g., raw materials, machinery, quipment, tools, spare parts and fabricated components, cam be conveniently ordered by reference to a national or manufacturer's standard. In such cases a standard code readily substitutes for a technical description in a purchase order specification (POS). However, for a particular item that will probably be required again, whether standard or not, it is often necessary to specify optional features that arc offered by the manufacturer. For such items, a standard format POS should be prepared as shown in Figure 7-14 so that a designer simply fills in blank boxes. The benefits arc

- unification of design philosophy,
- clear identification of features to be checked,
- fast issue,
- reduction in skill levels required to prepare specifications, and
- ready understanding by manufacturers of what is specified.

The greatest benefit is the contribution such formats make to widening the philosophy of standard material usage.



STEAM WINDLASS

NOTE : Fill * marked items without fail.

INSTRUCTIONS *

RULE AND GRADE			Q'TY [ ] ship set(s).		
TYPE, CAPACITY, AND QUANITY	CODE	SKETCH	RATE LOAD × RATED SPEED: CHAIN DRAM	RATE LOAD × RATED SPEED: HAWSER DRAM	QUANTITY
			t m/min	t m/min	
	HCEW		×	×	☐
	WECH (SYMMETRIC)		×	×	☐
	HECW		×	×	☐
	WCEH (SYMMETRIC)		×	×	☐
	CEHW		×	×	☐
	WHEC (SYMMETRIC)		×	×	☐
	HECHW	Nylon / Wire	×	×	☐
	WHCEH (SYMMETRIC)		×	×	☐
CHAIN TYPE	[ ] mm dia., U-3 [ ] . Kenter shacle [ ]				
STOWING LENGTH OF HAWSER	Nylon. [ ] mm dia × [ ] m	Wire. [ ] mm dia. × [ ] m			
AUTO-TENSION DEVICE	Yes / No	DRUM TYPE: Immtermediate flange. Yes / No	WARPING HEAD: Clutch. Yes / No		
OPERATION: SPEED CONTROL	Remote. Yes. No	Operation. Manual / Hydro			
OPERATION: BRAKE — CHAIN DRAM	Remote. Yes. No	Operation. Manual / Hydro			
OPERATION: BRAKE — HAWSER DRAM	Remote. Yes. No	Operation. Manual / Hydro			
OPERATION: CLUTCH — CHAIN DRAM	Remote. Yes. No	Operation. Manual / Hydro			
OPERATION: CLUTCH — HAWSER DRAM	Remote. Yes. No	Operation. Manual / Hydro			
NAME PLATE	Japanese , English , [ ]	Metric , Foot · pound			
OTHERS	Besides the above, the details of particulars, materials, accessaries, spare parts, tests, inspections, and painting accord with the provisions of STANDARDS OF MARINE INDUSTRIES and the followings :				

NOTICE FOR STANDARD MACHINERY APPROVED IN ADVANCE	Fill SD No. in one of this copy and return it immediately after this purchase order confirmed.	SD NO. APPLICABLE	SD-1621
GUARANTEE	Within 12 months after the ship's delivery	BUYER'S NAME	
Prepared for S No.	/ /	/ /	/ /

DEPARTMENT MANAGER	S NO.	JOB NO.
SECTION MANAGER		MAT. COST CLASS. NO. 3621(BOW)/3622(STERN)
ENGINEER-IN-CHARGE	PURCHASE ORDER SPECIFICATION FOR STEAM WINDLASS	MATERIAL CODE 362100000/362200000
DRAFTSMAN		DWG. NO. N3621000/N3622000

DIST.	
EST	1
B C	
P C	1
M C	7
Q C	1
S D	1
M 3	1
E O	1
FILE	1
TOTAL	11

SPARE PARTS BOX NO. H 103

FIGURE 7-14(a): Typical standard format for a purchase order specification; page 1.

DESTINATION	Design Dept.	Shipyard	LANGUAGE	Japanese / English
DOCUMENTS TO BE SUBMITTED TO SHIPYARD	S D	NON-SD		
	FINISHED	APPROVAL	WORKING	FINISHED
SPECIFICATIONS	6 copies	9 copies	10 copies	6 copies
ASSEMBLY PLAN	6	9	10	6
DETAIL DRAWING	6	9	10	6
ELECTRIC WIRING DIAGRAM	6	9	10	6
INSTRUCTIONS FOR INSTALLATION	6	9	10	6
SPARE PARTS AND TOOL LISTS	6	9	1 reproduc.	6
INSTRUCTIONS FOR OPERATION	6	–	10	6
SHOP TEST AND INSPECTION PROCEDURE	–	9	–	–
SHOP TEST AND INSPECTION REPORT	6	–	–	6
CLASSIFICATION SOCIETY CERTIFICATE	6	–	–	6
FINISHED WEIGHT LIST	Orig.& 5 copies	–	–	Orig.& 5copies
SUBMITTAL TIME	Delivery of Machinery	10 days after ordered	10 days after approved	Delivery of Machinery

GENERAL NOTES FOR DOCUMENTS:

1. Documents to be submitted in bookbiding.
2. Certificates to be submited to Quality Control Department at the delivery time.
3. Finished plans to be reproducible enough for their microfilming.
4. Working plans to be in Japanese by three copies.

NOTE:

FIGURE 7-14(b): Typical standard format for a purchase order specification; page 2.